

Sixth Australian
Fruit and vegetable
Storage Research Conference

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SIXTH AUSTRALIAN FRUIT AND VEGETABLE STORAGE RESEARCH CONFERENCE

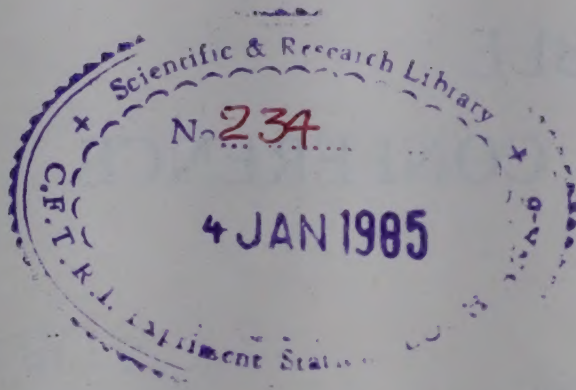
held at Cowes, Phillip Island, Victoria
October 23-26, 1972



PROCEEDINGS

Committee for Co-ordination of Fruit and Vegetable Storage Research

Sydney 1973



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FOREWORD

Conferences on Fruit and Vegetable Storage Research are amongst a number of technical conferences held under the auspices of the Australian Agricultural Council. This Sixth Conference was organized at the direction of the Committee for Co-ordination of Fruit & Vegetable Storage Research by the following sub-committee:-

Mr C.R. Brough (Department of Agriculture, Victoria), Chairman
Mr E.G. Hall (CSIRO Division of Food Research)
Mr D. Leggo (Department of Agriculture, New South Wales)
Mr I.D. Pegg (Department of Agriculture, Victoria)
Mr B.D. Richardson (Department of Agriculture, Tasmania)
Mr G. Fisher (CSIRO Division of Food Research), Secretary.

Papers took the form of either 45-minute reviews or 15-minute 'short contributions'; the papers have been edited but no attempt has been made to produce a standard format. The address of each author appears at the foot of the first page of his paper and the major points made in the discussions are included at the end of each paper or session.

Very wide coverage of fruit and vegetable research in Australia and New Zealand was achieved by the Conference. Complete lists of research projects and workers in Australia may be found in either the Australian Horticultural Research Newsletter or the Australian Vegetable Research Newsletter.

The Conference met at Cowes, Phillip Island, Victoria from October 23 to 26, 1972. It was officially opened by Dr D.S. Wishart, Director of Agriculture, Victoria.

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INTRODUCTORY REMARKS

Opening

The Conference was officially opened by Dr D.S. Wishart, Director of Agriculture, Victoria.

Dr Wishart referred to the large number of channels through which recommendations came to Standing Committee on Agriculture, and said that submissions on plant industry matters must be better organized and that any resolutions from this Conference should be progressed through the C.S.H.C.

Dr Wishart spoke of State finances and the competing demands by education, basic services, environment protection and other needs which influence the funds available to help agriculture. How should government funds be applied to help agriculture? Alternatives include (a) Compensation to farmers to cease production or to relieve overproduction in certain industries. (b) Research to improve efficiency and reduce unit costs. (c) Extension effort to fully utilize the known technology.

Dr Wishart said he was considering the recommendation which had already come forward for the appointment of specialist extension officers to promote the use of better storage methods and procedures. He was also considering how such a specialist extension operation would fit in with the recently established general regional extension service.

Finally Dr Wishart mentioned that, with the changes in the system of moving fruit and vegetables from producer through various storage procedures to the consumer, there were obvious benefits to be gained through research. The horticultural industry should be prepared to contribute to the costs of research and extension, as other industries have done.

Chairman

The Chairman of the Conference, Mr C.R. Brough, referred to the changing scope of fruit and vegetable storage research. There is now more emphasis on quality at the consumer level, although the problem of defining and measuring fruit quality has not been solved, and much more emphasis on packaging and handling, particularly in export, to reduce costs. He said that the economics of marketing is an important but neglected area which we can no longer ignore.

PRICE PATTERNS OF STORED POME FRUIT

B.B. Beattie*

The price of a seasonally produced commodity such as pome fruit can be expected to show a regular intra-year pattern. It would be expected that prices would be lowest at harvest and immediately after, and that prices would rise through the storage season as fruit become more scarce. On the other hand, prices between years would be affected by factors such as production levels, exports, and the extent of cool storage capacity.

In New South Wales there has been an exponential growth in pome fruit production over the past 20 years. Cool stores, both at grower-owner and co-operative level, have also increased substantially over this period in number and capacity. Because of the increase in production it could be expected that there would be a downwards trend in the prices of pome fruit in the long-term, with inter-year variations in price reflecting such factors as adverse weather conditions and on-year and off-year cropping. Intra-year price patterns would be expected to exhibit a general increase throughout the year. This pattern should show a substantial premium at the end of the storage year in the early years of cool storage. The price pattern of recent years, however, could be anticipated to show decreased premiums because of the increases in capacity of cool stores.

Inter and Intra-Year Price Fluctuations

In order to study these inter-~~and~~ intra-year fluctuations in price, data were obtained from the records of the State Marketing Bureau. The Bureau collects daily average wholesale prices from a sample of agents in the markets, and has the only consistent series available over the time periods proposed for study. The whole prices of Jonathan, Delicious and Granny Smith apples and Packham's Triumph pears were examined. Data for each variety for the period 1948-1957 and 1958-1970 were used for Packham's Triumph pears and Delicious and Granny Smith apples, and 1951-1957, and 1958-1970 for Jonathan apples. The data related to Fancy Grade Fruit with average counts of 96 to 180 for Delicious (approx. 76 mm - 64 mm dia), 113 to 180 for Granny Smith and Jonathan apples (approx. 73 mm to 64 mm dia) and 125 to 180 for Packham's Triumph pears (approx. 70 mm to 64 mm dia). These counts represent the majority of fruit offered for sale at the market.

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The monthly price data for the early period were graphed and showed a strong upward trend within years. This indicated that similar price patterns between months existed over this period of time. Price indices were therefore calculated from the data by a method used in an earlier study (Anon. 1958) of apple and pear marketing. From the daily average wholesale prices a series of monthly prices were computed which were then used to compute an average annual price for each of the years. The price for each month was expressed as a percentage of the appropriate average annual price, the average, for each month, of the deviations from the average annual price for the years, was taken as a price index for that month.

In the early period, covering most of the 1950's, the majority of fruit coming onto the market after storage was from cooperative cool stores, as orchard cool stores were only just beginning to be established. The patterns for the four varieties showed a clear overall upward trend in price between the harvest period and the end of storage. From June, the indices for Granny Smith apples rose steadily until September when supplies of coloured apples became scarcer, giving a sharp increase after this month. The price for Delicious apples from March to the beginning of May was generally low, when supplies were also in competition with the main Jonathan crop. During July and August heavy supplies of apples were generally received onto the market and the graph for this part of the season for Delicious shows price indices of close to 100 in this supply situation. Delicious prices rose sharply in September, as supplies of Jonathans began to diminish, and reached a seasonal peak in the middle of October.

Supplies of Packham's Triumph pears were almost entirely from districts in the Central and Southern Tablelands. A fair proportion of the crop was received from April to June, during a time when stocks of other varieties from both New South Wales and Victoria were available. The price peak was reached towards the end of September. The supply and price of Victorian pears largely governed price realizations for all varieties of New South Wales pears.

Since the late 1940's and 1950's there have been substantial increases in cool storage capacities which have caused considerable concern in the industry. Contributions to fruit industry periodicals have suggested that not only have general price levels been reduced but also that there has been a decrease in the premium received for cool stored fruit, over that of freshly harvested fruit.

The time period 1958-1970 was therefore examined for the four varieties. Before indices were constructed, the average monthly prices were again graphed and the same definite upward trend as for the previous period was noted. During the 1960's all varieties showed a trend towards later marketings than in the 1950's. This provides evidence of the extension of the marketing period through the use and better management of cool storage facilities. The inter-year average level of prices fluctuated considerably with no apparent pattern. The intra-year prices also showed some variation but the upward trend seemed to be linear and present in most years.

The seasonal price indices for 1958-1970 were then examined in relation to those for 1948-1957. Comparison of the patterns for the two periods does not indicate any substantial differences between the two; these being only a slight change in position, and the sale of fruit for a longer time in the second period, than the first period.

A series of linear regressions were then fitted to the original monthly price data for each year between 1951 and 1970. The data for each variety commenced in May and continued monthly to the end of the storage season. In virtually every year a positive correlation coefficient exists. Where a negative coefficient is apparent the regression equations usually are not significant. Another worthy feature of the coefficients is that there does not appear to be any trend in the regression coefficients over the years 1957-1970. Although the position coefficients also exhibited large differences between years, they also did not show any general trend in time. This indicates that the absolute price level changes from year to year, but in no recognizable pattern.

The regression coefficients were then regressed on years between 1951 and 1970. No regression was significant and the correlation coefficients were very low. This indicates that the rate of price increase within a year is independent of years. It may be concluded, therefore, that there has been no decrease in the price of these pome fruit varieties in recent years.

Varietal Price Levels and Prices for Controlled Atmosphere Fruit

All the price data examined suggested a considerable difference in the levels of prices for the different varieties. To examine this factor, graphs of the average monthly price for the years 1951-1970 for each variety were drawn. These figures showed clearly the relative value of each variety; prices for Delicious apples were well in advance of the other

fruit varieties; Granny Smith apples appeared to have the lowest prices throughout the harvest and storage year; Packham's Triumph pears and Jonathan apples lay between these two extremes.

Although some controlled atmosphere (C.A.) fruit have been marketed since 1967, and there are some data for 1968, a consistent series of prices has only been collected by the State Marketing Bureau since 1969. This limitation therefore, makes predictions about behaviour of prices more difficult for C.A. fruit than for fruit stored in regular stores. Because of the limited amount of data available, the average weekly prices of C.A. fruit were used instead of the average monthly prices. These prices were examined for the years 1969, 1970 and 1971 and compared with the comparable weekly prices for regular cool stored fruit.

The time when the C.A. fruit was first marketed in each season, varied both within years and within varieties. For each variety the length of time C.A. fruit was marketed after the finish of regular stored fruit also varied between varieties and years. Jonathan apples, a short storage variety, appeared on the market earliest in the storage season followed by Delicious and finally Granny Smith. Granny Smith, and to a lesser extent, Delicious, have been carried over into January and in 1970 sales were made into early February. The average price difference between C.A. and regular cool stored fruit over the 3 years 1969, 1970 and 1971, appears to be most for Delicious, followed by Granny Smith and Jonathan close together. This price differential appears to have been slightly reduced over these 3 years, from about 1 dollar to 90 cents.

Except for the fact that pome fruit is now stored for a longer time than in the 1950's, no other obvious changes are suggested by the foregoing analyses of price data. Granny Smith marketings have been extended into December-January and in some years February. Greater volumes of Delicious have come onto the market in December and January.

A discernible change in the price structure has not taken place even with these greater quantities of fruit on the market. It can, therefore, be reasonably assumed that these price patterns will continue at least into the near future.

REFERENCES

ANON. (1958). Some economic aspects of fruit marketing with special reference to seasonal price patterns. *Review of Marketing and Agricultural Economics* 26:81.

Discussion

Arising from the statement in the paper that there has been little change in price patterns through the year over a considerable period of time, the question was raised as to whether this had been looked at in 'constant' money values. This had not been done as the prime interest in this study was the pattern of prices through the year. The speaker conceded that with returns at constant levels and rising costs the grower had to counter his diminishing unit returns by increasing his volume.

It is interesting that best prices out of storage, both air and C.A. have been for Delicious apples. This is in line with price patterns generally overseas, large Red Delicious being generally preferred by consumers in many countries, thus following the American pattern.

SURVEY OF QUALITY CHARACTERISTICS IN WASHINGTON NAVEL
ORANGES SOLD IN SYDNEY RETAIL STORES

W.J. Greenhalgh and P.F. Ofner*

Despite interest shown by the citrus industry in the marketing of its products, there do not appear to have been any serious studies of what the shopper looks for and gets at traditional retail outlets.

Likewise there have been no real efforts made to question official standards of quality nor to question whether the criteria used have any real significance for the consumer. Research workers and those administering trade regulations apply the criteria of percentage juice, titratable acid and total soluble solids (T.S.S.) on the assumption that these are related to consumer acceptability, retail price or both.

Ideally, we should have wished to make a study relating some of the more objective quality criteria to the preferences of the consumer. While this still remains our long term goal, resources did not permit a survey of consumer preferences existing in a population such as that of the city of Sydney. It did, however, seem feasible to assume that price and fruit quality would be correlated in the highly competitive (?) situation found in suburban fruit retailing. We therefore set out to relate retail price to some of the quality criteria used in trade regulations and in research reports.

In addition to the assumption that price and quality would be closely related, we placed two further conditions on the study:-

- (a) That pricing policies would be more flexible in small retail shops than in supermarkets. The survey was therefore restricted to conventional greengrocers.
- (b) That unit price would vary with the socio-economic status of the suburb, and that this variable should be accounted for as far as possible when structuring the survey.

Washington Navel oranges were sampled from 24 suburban fruiterers on 3 different days, June 22, July 13 and July 20, 1971. The same fruiterers were included when the survey was repeated on June 20, July 11, and July 18, 1972. The fruit shops were selected in an arc of a circle equidistant from the City Markets; the suburbs being selected as representative of all status levels as determined by Congalton (1969).

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Status group	1	2	3	4	5	6	7
Number of shops	2	3	3	5	6	3	2

For each shop the price of all lines of Washington Navel oranges was recorded and a sample purchased from each line offered for sale.

Wherever possible, the district and grower were noted and any other information from the box or carton was recorded. When the oranges were brought back to the laboratory, data were recorded of length, width, weight, displacement weight, skin thickness, core diameter, juice content, titratable acidity, and total soluble solids and counts were made of the number of fruits retaining their buttons. Equipment was not available for measuring skin colour and gloss or juice colour.

These data were examined by correlation and regression analysis along with price of the fruit and the statistic representing the status of the suburb where the sample was purchased. The correlation co-efficients with unit price for the 2 years are shown in Table I.

TABLE I
Simple Linear Correlation Co-efficients of Unit Price
and 15 Variables

Year	1971		1972
Number of Observations	46	92	88
<u>Variable</u>			
Average weight	0.8066	0.8295	0.8242
Average juice content	0.8526	0.8220	0.8105
Average displacement weight	0.7885	-	0.8176
Average length	0.7891	0.8387	0.7385
Average width	0.7788	0.8108	0.7091
Core diameter	0.5394	-	0.5299
Acidity	-0.4299	-	-0.3242
Soluble solids	-0.3265	-0.3168	-0.3154
Percentage buttons	0.2915	0.1607	0.3565
Skin thickness	0.2250	-	0.3967
Length/width ratio	0.1379	0.3481	0.3684
Sugar/acid ratio	0.3071	-	0.2048
Relative density	-0.2006	-	-0.2515
Suburb status	-0.1768	-0.2155	-0.1038
Percentage juice	0.1439	0.0221	-0.0997
Significance of r			
p = 0.05	0.288	0.205	0.205
p = 0.01	0.372	0.267	0.267

The regression equations relating unit price and fruit weight were:-

Price in cents = $-0.94 + 0.028 \text{ weight in gms (1971)}$

Price in cents = $-1.66 + 0.033 \text{ weight in gms (1972)}$

That is, each 1 cent increment purchased a 35 gram larger fruit in 1971 and a 30 gram larger fruit in 1972. The lowest price paid was 2 cents and the highest price paid was 10 cents.

In the accompanying graph (Fig. 1), these retail prices are compared with wholesale prices at the time of the surveys and the ruling price for Navel oranges for processing into juice.

Similar correlation values were obtained using average juice content, displacement weight, length or width as the independent variable. It is concluded that price would be similar whether grading was by weight, volume, extractable juice, or, as at present, by width. Length gave a somewhat better correlation than width because larger oranges are more elongate than smaller ones; (note the positive correlation between the length-width ratio and unit price).

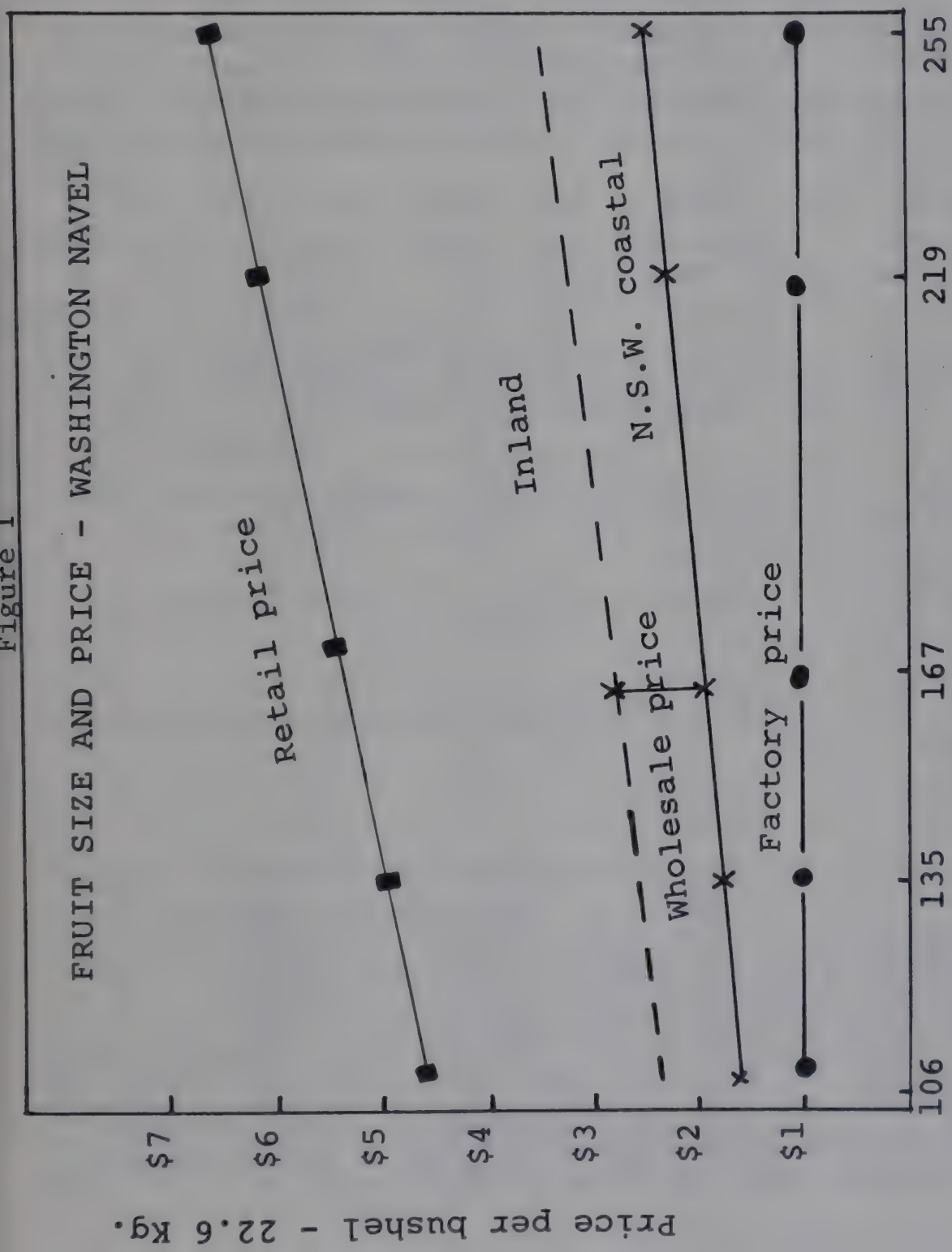
Even the best of the physical measurements of size gave a coefficient of determination of 0.65 or 65 per cent. Thus size alone was not an adequate determinant of price.

Both acidity and T.S.S. values correlate significantly but negatively with unit price. This is the dilution effect of size, probably accentuated by irrigation. Smaller fruit that are cheaper are usually the result of some environmental stress or high crop load. High levels of both acid and T.S.S. were associated with fruit from the Central Coast of N.S.W.; low levels were typical of irrigated citrus from the lower Murray. Fruit from the north-west of N.S.W. and from Queensland were high in sugar and low in acid.

Sugar and acid levels are important trade criteria early in the season when marketing of immature fruit has a depressing effect on the market. However, these criteria appear to have little significance during the major part of the harvesting period. Further research is needed to determine whether the low levels of both sugar and acid in large, highly priced fruit are a disappointment to the purchaser.

The correlation between sugar-acid ratio and unit price was barely significant at the 5% level. Sugar:acid ratios are used in some countries and by some research workers as a measure of quality.

Figure 1



(198-235) (163-180) (125-150) 88's.

Pack counts

The negative sign of the non-significant correlation between unit price and suburb status is the result of status ratings being arranged with unity as the highest status and 7 the lowest status. The trend towards higher prices being asked in higher status suburbs was only weakly evident and statistically non-significant. It should be pointed out that in both seasons the market was heavily supplied with fruit from the Murray region and fruit was freely available in all suburbs irrespective of assumed capacity to pay.

Percentage juice showed no correlation with price. 'Dry' fruit was not a problem in either season or at the time of the year when the surveys were conducted.

Information of interest to the trade was obtained on incidence of fruit without buttons; incidence of waxing, branding, etc.; number of lines on offer at each retail outlet; lot sales as compared with piece sales and retailer resistance to fruit from certain districts. There was evidence that mixing of branded and unbranded fruit is fairly common and there were occasional instances of mis-description. There was no instance of short-selling.

This study was financed by a R.C.D.F. research grant.

REFERENCE

CONGALTON, A.A. (1969). "Status and Prestige in Australia". (Cheshire).

Discussion

When asked whether blemish was common on the fruit sampled and whether it was an important factor in determining price, the speaker said that the fruit examined had mainly come from inland districts and was generally free from blemish. He regretted that it had not been possible to include rind colour in the survey and agreed that it must influence price.

Retailers had not given any lead as to how they arrived at the retail price for any particular lot of fruit but the higher the quality of the fruit the greater the difference between wholesale and retail price (mark up).

THE DETERMINATION OF OPTIMUM STORAGE CONDITIONS FOR LOW TEMPERATURE STORAGE OF FRESH VEGETABLES

M.D. Littmann*

The aim of this paper will be to examine various concepts which are involved in the determination of optimum storage conditions for low temperature storage, and to draw attention to possible differences in interpretation of the meaning of related terms.

Terms

The term 'optimum storage conditions' will normally have one of two general meanings:-

- (a) Those conditions of storage which result in optimum quality (the time after harvest and the market being given).
- (b) Those conditions of storage which maintain a commodity for the longest period (at some given standard of acceptability).

There will be, also, a number of 'optimum storage conditions' within each of the above sections, depending upon variations in the standard of acceptability, location of market, etc. These will be considered in more detail below.

The term 'vegetable' has been used in a liberal sense: some relationships between commodity performance and temperature have been included for discussion although they are only known to apply to commercial fruits.

Temperature and Storage Life

Respiration makes energy available for living processes, and it is frequently accepted that in post-harvest plant tissues, the quantitative relationships which exist between temperature and respiration rate (e.g., Q_{10}) are the same that occur between temperature and deterioration rate. Whatever the merits of this view, rate of deterioration in a vegetable is generally reduced by decreasing the temperature over a fairly wide range, commercially speaking.

The factors which eventually limit the downside extrapolation of this relationship are chilling and freezing. The optimum storage temperature normally will be related to the temperatures at which chilling or freezing occur. A third situation, where intermediate temperatures are less effective, also occurs.

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Freezing

In vegetables which do not chill, the theoretical optimum storage temperature is the lowest temperature at which freezing does not occur. The freezing temperature of vegetables is determined largely by solute concentration of the cell sap. Freezing temperature therefore normally varies by only a few degrees.

Because at these temperatures small variations in temperature may produce catastrophic changes in quality (i.e., the product may freeze) and because the concept of optimum storage temperature is basically commercial, any statement to industry on 'optimum storage temperature' should allow some margin for safety. Allowance should be made also for variations in cold room temperature both in time (refrigeration cycling; accuracy and stability of thermostat) and in location throughout the room.

Chilling

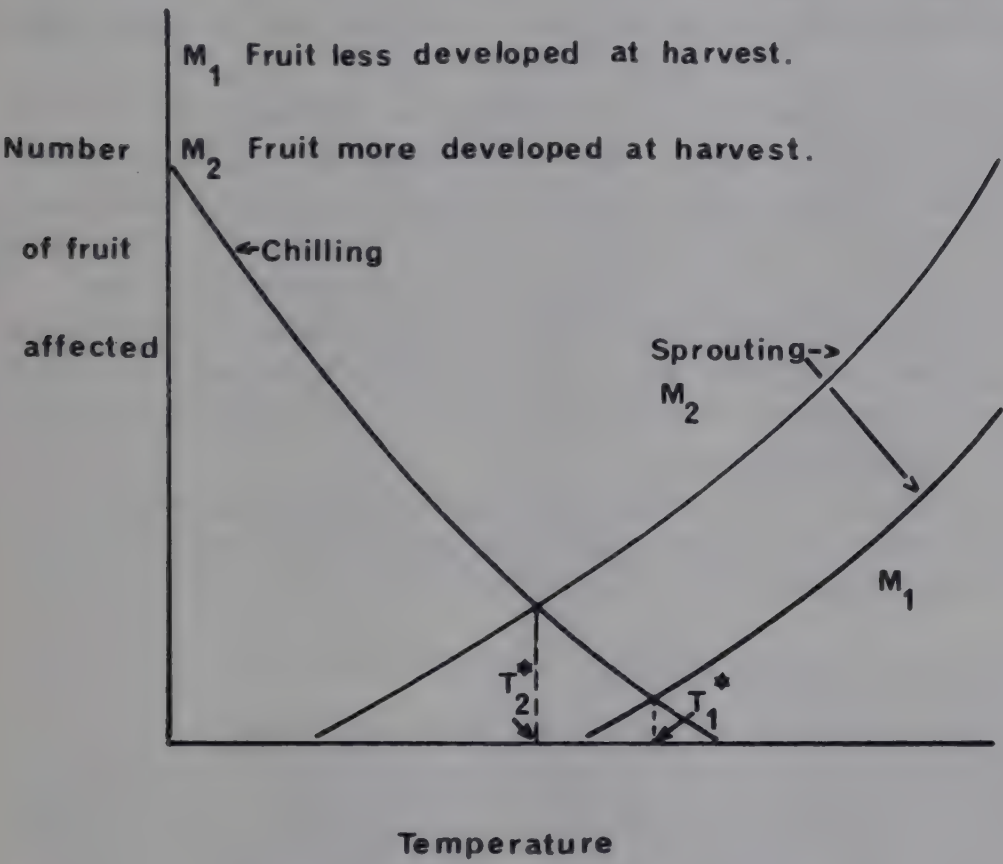
The term 'chilling' in vegetables is used to describe obvious physiological disorders which occur during cold storage, but at temperatures above freezing. Chilling injury is usually most severe in sub-tropical and tropical products (especially those which are fruits, in a botanical sense, e.g., tomatoes, chokos) although temperate commodities are not immune.

Chilling occurs over a wider temperature range than freezing, and at high temperatures, where other forms of deterioration may be significant, where a number of types of deterioration are occurring together, each may respond differently to temperature. The optimum storage temperature thus occurs where the sum of total disorders is at a minimum. In work that we have done into cold storage of choko (*Sechium edule*) fruit, the optimum storage temperature was related (*inter alia*) to both chilling incidence, and to the development of sprouting - both factors reducing acceptability of the product. From Figure 1 it may be seen that the effects of these factors must be combined, to arrive at an optimum storage temperature. In this example, even if stage of development of the fruit has no influence on its propensity to chill, or on rate of (not time to) development of sprouts, the more developed fruit (M_2) have a lower optimum storage temperature.

With chokos, the situation was further complicated by the operation of another influence: these fruit were found to exhibit a number of chilling disorders, which were different in both temperature and time of appearance. Thus the storage

FIGURE 1

Numbers of fruit affected after a given time in storage.



- * 1. Minima do not necessarily occur where the curves intersect.
 - 2. Total affected fruit does not necessarily equal the sum of the above curves.
- Some fruit are both chilled and sprouting.

temperature which yielded optimum quality after 2 weeks storage was different from the temperature yielding optimum quality after 4 weeks storage (the quality levels, however differed greatly).

Intermediate Temperatures

There are occasions when optimum storage temperature is not closely related to either freezing or to chilling in the sense used above.

On these occasions, deterioration proceeds faster at intermediate temperatures (e.g. $36-40^{\circ}\text{F}$) than at temperatures above and below these figures. South African workers have found that plums stored at 37°F were less acceptable than those stored at either 32°F or 40°F . Work in our laboratory has confirmed this, where it has been shown that Doris plums were less acceptable after storage at 32°F or 35°F than at 30°F or 55°F . Similar effects have been found with grapefruit and peaches in other laboratories.

These reports refer to the occurrence of the phenomenon in fruit. Although I am not aware that it has been reported in vegetables, a comment seems relevant in the present context.

Commercial Objectives and Research

A research worker, faced with the problem of defining optimum storage conditions must clearly establish, early in his deliberations, the exact purpose for which cold storage is required. This need arises because different approaches may be required for different purposes.

The objectives of cold storage in commerce are:

- (1) To provide a commodity at a given market in a more acceptable condition
- (2) To avoid waste by holding surpluses until supply diminishes
- (3) To hold produce for a period, so that a high market price is obtainable when supply diminishes
- (4) To allow exploitation of more distant or otherwise inaccessible markets, or
- (5) To allow ultimate users to keep produce for longer periods of time (e.g. supplies on board ship).

To take an example: the optimum conditions of storage for a commodity which is being transported for 3 weeks, and then subjected to a seven-day post-transport marketing period, may

be quite different from the conditions which are most suitable when use occurs immediately on removal from storage (e.g. tomatoes).

Sources of Variability

Biological variability is perhaps the most taxing of the many problems which are met in the design and interpretation of experiments with living organs. Conflicting results from apparently duplicated storage experiments are common. During their growth, no two plant organs receive identical stimuli from the complex environment, and large seasonal differences and location of the crop, cultural practices and harvest date may influence the response of a harvested fruit or vegetable to its storage environment.

The determination of commercially acceptable optimum storage conditions can thus be made only against the background of data gained from work which has been done over a number of seasons, and generally from a selection of growing areas. The consequent volume of commodity required and the expense of its provision for experimental purposes generally entail the enthusiastic researcher, at some stage, in reducing his research ambitions, and in seeking assistance from a biometrician.

Maturity and Ripening of Fruit

Where fruit are ripening during storage there is an added consideration: the temperature at which a ripe fruit can be successfully stored may not be a temperature at which ripening will properly proceed. Also bananas and apples are known to be more susceptible to low temperature injury when passing through the respiratory climacteric. The criteria by which acceptability is judged, therefore, becomes a determining factor in arriving at optimum storage conditions.

Data

The difficulties which occur in defining and obtaining a satisfactory measure of quality, are well known. The criteria by which quality is assessed may influence the decision of which storage conditions are considered to be optimum.

Deciding on the criteria that should be chosen to measure quality involves the worker in this field in considerations of the market, and the manifestations of end of storage life: is there an undesirable colour, taint, odour or texture? Is the feature internal or external? Is it apparent when first removed from store, or does it become apparent only on removal? Can it be measured objectively (generally a good technique for showing differences) or should it be measured subjectively by a panel? (a good technique for establishing acceptability).

In commercially orientated experiments, a useful source of criteria may be the legal grade standards of the appropriate market.

Conclusion

In this paper, I have attempted to examine briefly some of the more important concepts and problems which are of interest to the worker in the field of commercial low temperature storage. It is clear that the search for an optimum storage temperature must be related to the various conditions and requirements of the particular market being considered at the time.

Discussion

The speaker agreed that the figure in the paper was rather simplified and the crossover point of the curves for chilling damage and sprouting did not necessarily define the optimum storage temperature. Comment supported the speaker's emphasis on the need to take into account the intended utilization of the vegetables after storage in determining the optimum storage conditions. It was agreed that it might be possible to use sprout inhibition to delay sprouting of chokos in storage.

PACKAGING AND PRE-PACKAGING

I.D. Peggie*

Two groups of people are of prime importance in the fruit and vegetable industry - the producer and the consumer. All others, whether wholesalers or retailers, truckies or agents, box makers or shipping companies, only facilitate the transfer of a commodity from the producer to the consumer.

Many of these intermediaries are powerful groups, and their demands on packaging must be met. Often these are sensible, such as good ventilation to avoid overheating during transport. They may, however, require the producer to pay more for his package, such as making a carton very strong to withstand high warehouse loads rather than use pallet racks, or put up a fancy presentation to please a buyer but which confers no benefit on the produce.

From the point of view of the producer, economics demand the use of the cheapest possible container that will do the job effectively. And the consumer has little concern with the package provided he gets the produce in what he regards as field fresh condition.

At the last Conference I listed the requirements of a fruit and vegetable package, as described by Hardenburg (1966). Other aspects of packaging were by Tugwell on "Packaging Fruit in Plastic Film", O'Loughlin on "New Developments and Problems in Apple and Pear Packaging", Schoorl on "Evaluation of Package Performance" and Middlehurst on "The Influence of Carton Material on the Cooling of Fruit in Containers". The present review will mostly consider what has occurred since the 1968 Conference, particularly as it affects the producer and the consumer.

Effect of the Package on the Produce:

The package at best can only reduce the deterioration in quality of the produce, with the possible exception of allowing ripening to take place during shipment or marketing. Hardenburg (1971) reviewed the effects of packaging treatments, and especially the effects of plastic films used for prevention of moisture loss or for atmosphere control on the keeping quality of fruit.

The commonly used polyethylene film has quite a high permeability to oxygen and carbon dioxide, yet respiration rates of produce at market temperatures may often be so high as to build up injurious levels of carbon dioxide. Stewart and Uota (1971) found that 'brownstain', observed in lettuce

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from rail cars and road trucks, was due to CO_2 concentrations of about 2% or more, and that attempts to ship lettuce in low O_2 atmospheres to gain an improvement in general condition were unwise. The same condition could occur in plastic lined or heavily waxed cartons, especially in a tight store, even at temperatures around 3°C .

Sealed polyethylene bags have been used successfully for some products, ranging from watercress (Anon 1969) to gooseberries (Kenny 1971) and pears. Varietal effects with pears are important. Packham's Triumph show no ill effect in high CO_2 levels, whilst other varieties are quite severely affected. Perforated bags are used for these varieties when exported from Victoria, or sealed bags having a sachet of lime included with the fruit to absorb excess CO_2 are used in Tasmanian pear shipments.

A problem has arisen with poly lined pear cartons if they are given methyl bromide fumigation on arrival in U.S.A. The bags must be slit before fumigation, and even perforated bags are not regarded as sufficiently open to avoid this extra handling. The industry must now look at alternative treatments such as waxed or plastic coated cartons to keep moisture loss as low as possible without affecting fumigation efficiency.

The use of polythene bags as a case liner for bananas was reported at the 1968 Conference. The preliminary studies mentioned then have now been developed into a most effective packaging treatment. Scott, McGlasson and Roberts (1968) described the effects of ethylene on the ripening of bananas. They used potassium permanganate on vermiculite blocks to absorb ethylene within the package, and thus prevent the bananas ripening.

Grape experiments conducted in Victoria have investigated film liners and plastic cartons for grapes. If grapes are treated with an effective fungicide the high humidity conditions ensure a minimum of berry shrivelling and stem drying and browning. However, the commonly used metabisulphite treatments can cause severe fruit injury under warm moist conditions when the fruit is removed from cool store for marketing.

Successful shipments of traypacked Golden Delicious have been reported by a Victorian exporter, who shipped green coloured fruit as desired by U.K. buyers. Prompt cooling and a non-sealed polyethylene bag carton liner outturned the fruit in excellent condition, with no shrivelling or bruising.

One pallet unit treatment which may prove useful is the shrink film, applied around the sides and top of a stack of normal cartons (Anon 1971). Originally introduced as a unitising technique its side effect on moisture control may be just as important. A disadvantage could be an increase in moisture content of the fibreboard material and consequent loss of stack strength. Local plastics manufacturers have equipment available for this technique.

Although the plastic bag has been a most successful treatment, it is a nuisance to the packer and requires additional shed staff to insert and close the bags. Alternative moisture control treatments are therefore being sought, even if they are not as efficient as the plastic bag and have no CA effect, provided that they are easier to use in the packing shed.

A new development with interesting possibilities is in insect resistant packaging (Yeadon *et al.* 1971). Although applied to the package to prevent ingress of insects, it may have an application as an in-package sterilization treatment. The FDA approved material used in the U.S.A. trials was a mixture of pyrethrin and piperonyl butoxide carried in a castor oil base.

PACKAGE MATERIALS:

1. Wood

Changes have been steadily taking place in fruit and vegetable packaging. The Australian Apple Box, or 'dump' case previously used in southern States for apples and citrus has virtually disappeared from the markets. Similarly the long bushel pear box has been eliminated from export use and will soon finish in local markets. As secondhand cases these two cases were the prime market containers for apples, pears and stone fruit. Growers of these fruits have been forced to provide new containers, usually cartons. Similar use was made of the banana and pineapple boxes, particularly for pome fruit and vegetables. Experimental shipments to U.K. of various wooden case treatments, mainly of pears in the standard case and long bushel case, were conducted in 1967. By 1971 the long bushel was almost eliminated from export. For local use, however, many boxes are still used as returnable containers and are likely to remain in circulation for many years. Even old 2 x 4 gal. kerosene cases are still in use for apples. Wooden trays are commonly used overseas, possibly because of good stack characteristics.

Wirebound wooden boxes came onto the Australian scene for citrus and have been tested for many products. Their use has settled down to citrus, particularly for export, and for celery.

Like other wooden boxes they have excellent stacking strength but the awkwardness of using and reusing them has gone against their general acceptance.

2. Fibreboard

Within Australia, as in many other countries, the fibreboard carton has become the main package for fruit. Changes within the carton industry have been small but numerous, resulting in the present cartons being of a high standard. Australian eucalypt short-fibre pulp gives a lower resistance to puncture but a higher stacking strength than long-fibred softwood pulp. Improved papers and glues, automatic sealing and high quality printing give an attractive and efficient package. However, skilled supervision and adjustment of carton making up and sealing equipment is necessary to avoid substandard packages, and this is too often not provided.

The introduction of waxing has greatly improved the wet strength and stability of cartons. Waxed inners are very effectively used for bananas and many vegetable crops, and increasing use is being made of waxed open top local market cartons. Wax may be applied by dipping or as a surface coating; the latter process gives a most attractive appearance and some shower resistance, but uptake of moisture by these cartons is only retarded and their wet strength is little better than uncoated cartons. Plastic coatings are also applied which produce similar effects to wax coating. Heavier plastic films, however, can be laminated to fibreboard, and allow a much higher humidity to be retained within the package.

Waxed and plastic coated cartons are difficult to seal and automatic glue sealing equipment cannot be used. The hot melt sealing process or stapling are more expensive and slower procedures, and have tended to limit the use of waxed cartons.

The very big demand for waxed cartons has led to a world shortage of suitable high grade wax. Alternate application methods have been investigated, and a CSIRO technique of drawing wax up the internal corrugation, leaving the outside surfaces uncoated, gives high carton strength without affecting appearance or glue sealing. A different approach is the Lepelising treatment of plastic, using a high density spark treatment which slightly modifies the film to permit glue adhesion. This may allow wider use of plastic coated fibreboard. Side wall reinforced cartons use an extra layer of paper, preferably waxed or plastic coated, glued to the inner walls of the carton, leaving the normal surface on the carton flaps for glue sealing. This gives a strong carton, and could be used with top and bottom moisture proof sheets. It may be reasonable to use pads covered with a moisture proof liner for a tight fill pack.

3. Plastic

Moulded polystyrene boxes have been used in Europe for many years. High volume production and relatively low material cost have encouraged their use, together with their light weight, insulation value, moisture proofness, and attractive appearance. Handling techniques and good design have overcome the basic disadvantage of their fragility. Various attempts have been made to introduce them in Australia and successful marketing of stone fruit was achieved. The higher production costs and the remoteness of crop production areas from manufacturing centres, coupled with the inflexible attitude of most people who are required to handle them, have thwarted most efforts.

'Corflute' extruded copolymer material was devised in Japan and tested as fruit cartons in Victoria in 1968. This material has an internal ribbing providing a similar structure to corrugated fibreboard. It is light, very tough and not affected by moisture. Export trials conducted in 1969, 1970 and 1971 by the Australian Apple and Pear Board showed it to have considerable potential as a fruit package. Provision of ventilation for cell and traypacked apples was found necessary and external condensation on the cold cartons was a nuisance factor. Unfortunately the material price rose to a point which far exceeded fibreboard and 'Corflute' is not now used for fruit or vegetables. Grape storage trials in Victoria in 1971 were impressive and the material may be reconsidered if the price difference between plastic and fibreboard is reduced.

Injection moulded plastic boxes have not been used for fresh produce apart from berry punnets. Recent interest has been shown in plastic crates for vegetables, and in a uniform returnable plastic box made in a number of interstackable sizes, for a large range of crops.

4. Internal Fitments

Various forms of internal strengthening, positioning or cushioning have been used within packages. The most common is the cell pack for apples. Made from corrugated fibreboard the cells can be used by fairly unskilled packers to row in naked fruit, providing good protection against bruising, whether from impact or load. The cellpacks have a basic problem of requiring several sizes of package to accommodate the range of export counts, which leads to problems in palletising, transport and warehousing. Attempts to use a two height series to overcome some of the shipping problems were only partially successful but other problems are still unsolved.

Another attempt to overcome this problem and use a single size carton was the honeycomb type cell divider, mainly marketed in Australia as 'Dufaylite' expandable cells. This gave a much better volumetric efficiency within the carton but packers found it difficult to handle and packing time was increased by about 15%. It did not provide the same stacking strength as conventional cells and has now been discarded from export. However, it is still widely used in U.K. and by a few packers in Australia.

Many types of trays, or formed layer pads, have been tried out throughout the world. The most common type is a moulded paper pulp tray with cups formed to the general shape of the fruit. The fruit is normally wrapped which assists in reducing the amount of fruit movement and consequent abrasion. An inverted 'capper' tray is usual for the same purpose.

Many types and qualities of pulp trays have been tested. Modern machinery is now capable of producing smoother tray surfaces, with less lumps and more cushioning. Moulded columns designed to support one tray on another have been tried, with the aim of having the weight taken by the trays and not the fruit. They have not been very effective, either because the columns cannot take the load, or slightly small fruit is able to rattle around in its cell. A recent development in North America aims at avoiding the necessity for wrapping by better cup shaping and the use of a foam polystyrene capper tray (suitable for all counts) to provide a slight pressure inside the pack to eliminate fruit movement (Anon 1971).

Moulded polystyrene trays have been tested over the past decade with variable success. Many early attempts were too brittle, particularly with excessive cracking in the direction of extrusion. South Africa has used polystyrene trays since 1969, initially because of comparatively high pulp prices. The tray is fairly thin and tough in comparison with the trays developed in Australia. The requirements finally met by local manufacturers were for a cushion or pad with sufficient softness to allow the fruit to bed in and be gripped, thus eliminating fruit movement, and for as little brittleness as possible.

Pulp trays avoid any condensation and have a very good resistance to breakage, polystyrene trays do not absorb moisture, have a better cushioning effect and consequently less fruit bruising. Claims that non-wrapping of fruit leads to increased fruit damage have been substantiated in the past, but improved trays and better handling methods such as pallet units and containers now permit the elimination of wraps without undue fruit injury. This offers a cost saving in materials, but more importantly requires less skilled packing labour.

The Scoresby traypack was developed in Victoria for container use and subsequently for unitised pallet shipping. A smaller package than the standard traypack was required, and to achieve the maximum net weight of fruit meant a return to the diagonal packing system. This requires more skill by the packers but this disadvantage is greatly offset by the reduced package and freight costs.

Traypack for pears are not widely used. They only appear warranted for high quality, easily damaged varieties such as Comice. Traypacks may, however, be an alternative to the wrapping of pears. The cost of trays would be only slightly higher than wrapping, and would use less skilled labour, but shipping freight rates based on volume would be substantially increased.

Moulded PVC trays have been effectively used in packs such as the half-bushel 'Wincrib' units for apples, and for a variety of single or multi-layer packs for stone fruit. These thin trays provide excellent positioning of the fruit but have no cushioning effect between layers. They give good protection to fruit in single layer trays, with a very attractive appearance, but can do little more than prevent fruit movement in multi-layered packs.

A few attempts have been made at surface coating trays to control mould, superficial scald or other disorders. Both pulp and plastic trays can be chemically treated during manufacture, and it is likely that elimination of wrapping will be encouraged if tray treatment could replace the effect of special wraps.

5. Carton Supports

Stacking strength of cartons has been criticized, and growers are forced to provide cartons of high strength, at a high cost, to avoid fruit damage in cool store or on board ship. Strengthening collars or corner supports were tried, and although fairly effective, were not generally adopted. They are in use for grapes, in the form of an H divider in the half-standard bushel grape carton.

Interest is now centering on the use of external supports, such as pallet racks and crutches to carry the weight of added pallet loads, and cartons are only required to take a limited load about 2 metres high.

6. Package Disposal

One problem with all packages is getting rid of the used packaging material. This is an increasing problem in big cities and can be very costly. This was noted in Covent Garden

where carriers had to be paid to remove expensive but 'disposable' timber pallets. Steel strapping used for pallet unitising was a major annoyance in the same market.

Plain fibreboard cartons are the most readily disposed unit, either by burning or repulping, and a few major repackers have introduced equipment to profitably dispose of fibreboard. Unfortunately waxing and plastic coating create problems in recycling pulp but can be overcome with somewhat more expensive processing.

Plain timber cases are easily burnt, but wirebound boxes are regarded as a nuisance, no matter how they are destroyed. Plastic, particularly moulded polystyrene, is a world wide pollution problem. They can be burnt in suitable incinerators with no deleterious byproducts, and in fact can be of merit in assisting disposal of associated material. Plastic materials are also being developed which are readily broken down on exposure to light, though this may create more problems than it solves. Water soluble hydroxypropyl cellulose, with easily destroyed inner and outer protective film coatings, has been produced as bottles at a cost comparable to glass, so we may expect future developments in plastic packaging along this line.

Packing Techniques

Traditional packing, placing the fruit in precise patterns determined through packing charts according to fruit size and shape, has been the hallmark of a good operator. This method is costly of labour, but does make the most efficient use of the space available, and gives an attractive presentation. It may be used to hide fruit defects, but of more importance is the damage that may be caused to the fruit by packing pressure. This was clearly shown with Queensland tomatoes on southern markets in half bushel boxes, in contrast to the present general acceptance of the loose filled tomato carton now used.

Machines have been devised to do the packing. They have been of doubtful value and are not in large scale use. Better success has been achieved by assisting the packer with easier procedures. The rapid pack system for oranges is an example of this. Elimination of fruit wrapping, good sizing and better sorting enable only moderately skilled packers to do a good job with packs where fruit placement is defined.

Volume filling was looked on as the big hope, but the industry has long known that fruit able to move in the package is liable to injury. Tight fill techniques overcome this. In tight filling, the fruit is filled at random into the package, vibrated to settle the fruit, and lidded with a

compression pad to prevent fruit movement. This gives less transit injury than place packing for fruits adapted to the method, such as peaches, apricots and plums; it reduces labour requirements, both in skill and in number depending on the amount of mechanization used (Mitchell *et al.* 1965).

Buyers accustomed to pattern packing may need to be convinced that tight filled produce is in fact a better pack. Change-over to tight filling requires expensive equipment and probably new packages, as cartons must be rigid to withstand bulging and for adequate settling must have a depth about three or four times the diameter of the individual fruit. Sale by volume of package, such as a 20 or 30 litre pack is possible, in lieu of the bushel or half bushel traditionally used. However, a minimum net weight may be required to satisfy buyers that they are not being hoodwinked.

Schoorl (1971) has reported Mitchell in U.S.A. as estimating that 70% of pears and 60% of plums are now tight filled. There can be little doubt that tight filling of many fruits and vegetables will occur in Australia, particularly for local and interstate trade. The attractiveness of protective pattern packed produce may force the export trade to persist with it on highly competitive, quality conscious markets.

Prepacking

Most of the detail of prepackaging was described at the 1968 Conference (Peggie 1968). There seems to have been few advances in this field, mostly confined to improvements in films, trays and machinery.

The basic argument still occurs as to where prepacking into consumer units should take place. The central warehouse (Shaffer 1966) where produce is accumulated and stored, and prepacked to order, seems a most logical and efficient procedure. Good equipment can be efficiently used, and standard packs in over-wrapped trays, plastic or net bags produced quickly. This minimizes the delay between packing and sale so that damaged produce should be avoided.

The alternative proposal is packing at the point of production, so that all waste is kept on the farm, such as with outer leaves of cauliflowers, and the produce is only handled once.

Both these systems are in operation in Australia, but much more could be done to avoid the bad handling and high wastage levels which now prevail.

Australian Export Packages
Shipped to U.K./Europe

	'000 bushels				
<u>Apples</u>	1964	1966	1968	1970	1972
Boxes	5128	2765	845	623	273
Cells	1500	3812	3873	3846	2001
Trays	300	486	404	796	931
Bulk	100	42	182	35	492

Pears

Boxes	1625	1979	1340	369	66
Cartons			13	1042	1129
Units			67	2	11
Bulk				10	

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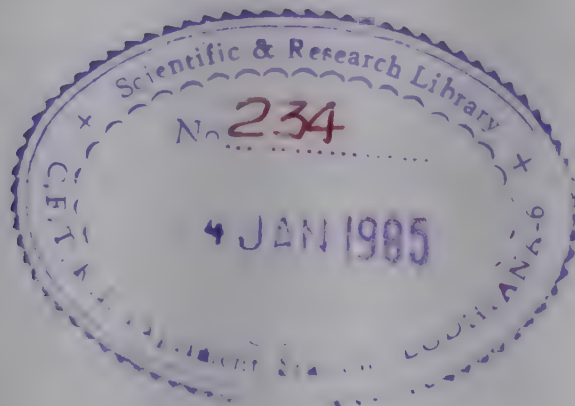
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Discussion:

The discussion raised some basic questions.

How important is presentation (in the package) in marketing of fruit and vegetables, does it affect consumer buying? Probably not. Therefore the best packaging is that which delivers sound produce at lowest cost. Who is going to make the necessary major changes in packaging and handling? Can the industry do it? The paucity of basic information on marketing is a big handicap.

The Scoresby traypack (now called the Australian Tray Pack - Ed.) has been very successful because it has reduced costs and it will soon be the standard pack for apples.



HANDLING AND TRANSPORT OF FRUIT AND VEGETABLES

J.B. O'Loughlin*

Since the last Fruit and Vegetable Storage Research Conference, the development of fruit and vegetable packages has been influenced by two new concepts in handling and transport, namely containerisation and unitisation, together with a re-examination of the possibilities of bulk handling in both systems. Undoubtedly the container concept of handling has been the most spectacular, but considering exports of apples to the United Kingdom and Continent earlier this year, container shipping took less than 20% while unitised packs carried approximately 37% of the total. By contrast, containerisation of pears was of far greater significance than unitisation.

Other handling and transport methods to be considered in this paper are the development of re-usable packages, the possibilities of air transport and developments with packages still handled individually. Road and rail transport have not been covered directly as they tend to accommodate the packages designed for other purposes. Their period of active research development was prior to the last storage conference. This review is intended to concentrate on Australian developments since the 1968 Conference and to complement Mr Peggie's review of packaging and prepackaging.

Unitisation

Unitisation is considered to be the palletisation of fruit and vegetables (in this context) from packing shed for shipment as a unit to at least the primary importer or merchant. This is distinct from the use of pallets to handle loose cartons or cases from packing shed to the ship after which they are handled individually. The ultimate development of unitisation would be from packing shed to a large retailer who would exhibit produce for sale on units. In this way the only time that the individual packs would be handled would be when customers took them out of the units.

Although overshadowed by the more spectacular container concept, unitisation of fruit and vegetables should result in some relief from increasing handling, discharge and delivery costs. It should also ensure speedier turn round of shipping as well as overcoming much of the costly dockside sorting of produce at discharge into brands and shipping marks. Unitisation also offers the prospect of improved fruit outturn

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through the faster delivery and reduced bruising which often occurs with multiple handling of single packages. Although unitised shipments of apples (the major product being unitised in Australia to date), at present lack the regularity of container shipments, they are much more flexible since they involve modules of 40" x 48" x 72" instead of 20' x 8' x 8'.

Hall and Hales (1964) reported that initial export shipments of both apples and pears on strapped pallets greatly reduced bruising. However, these trials were not followed up with extensive commercial shipments as the pallet modules used had a much poorer stowage factor than boxes or cartons stowed loose. Also the method of unitising cartons (vertical straps) was unsatisfactory as the straps slackened when the cartons settled. Limited shipments of unitised boxes of apples and unitised long bushel pear cases were made from Tasmania but much of their value was lost when straps were cut immediately on discharge in U.K. Up until 1971 only small quantities of special unitised packs such as Pal-paks, Win-cribs and Sainsbury crates were sent overseas.

During this period Boyes (1967) considered that the vessels then available for refrigerated cargoes were not designed for unitised packs. If they were used, he claimed there would be a considerable understow. However since that time, vessels have been designed to carry cargo on pallets of approximately 1200 x 1000 mm with a unit height of approximately 1850 mm.

The first significant commercial shipments of unitised fresh fruit were from California to Japan by Salen-Interocean Inc. Elms (1970) examined the operation wherein the Sunkist organisation developed a 35" x 42" skid pallet holding six layers each of seven cartons of citrus column stacked to an overall height of 71". The cartons were held in place by means of twine and rubber bands around the stack on the top and third layers and fibreboard binders between two rows of cartons at the second and fourth level.

After preliminary local tests in Tasmania to unitise apple cartons, shipping trials were organized for the 1971 export season using 140/160 count cell cartons unitised on 40" x 46" pallets and Scoresby tray pack cartons unitised on 41" x 48" pallets. Richardson and Walker (1971) reported that the method of unitising, i.e. palletising adhesive together with horizontal strapping was basically successful. The main problems were associated with some carton damage if units were dismantled overseas in a very damp condition. The success of the unitised Scoresby tray packs meant that the Export Apple Industry had a one sized pack that could be either containerised or unitised (although it did not fit the standard 40" x 48" or 1000 x 1200 mm pallets).

Prior to the 1972 export season, O'Loughlin and Richardson (unpublished data) produced an improved 4 way entry 40" x 46" pallet with 75% top deck coverage and 45% bottom coverage. At the same time they explored the possibilities of pallet dimensions to accommodate existing apple and pear cartons. Their solution - a 1200 x 1175 mm pallet - was unacceptable to shipping companies who preferred the alternative 42" x 47" dimensions. Although this was used in Western Australia during 1972, its use was not permitted in Tasmania due to differences in heights for different packs.

At the same time O'Loughlin (unpublished data) modified the Scoresby unit onto a 4 way entry 42" x 46" pallet with internal vertical supports and a timber lid. During the 1972 export season approximately 250,000 bushels of apples were exported from Tasmania using this system. The main problems involved a tendency for lids to be damaged when handling adjacent units.

It is difficult to obtain accurate costs as they vary from shed to shed depending on when cartons are purchased, whether cartons are unitised off the packing line or not and the level of shed management. A base estimate of the local costs for 160 count cell packs would be 82¢/bush. This cost includes 72¢ for carton, 7¢/bush. for pallet, 1¢/bush. for strapping, glue etc. and 2¢/bush. for labour. Some estimates have put the labour cost as high as 7¢/bush., but this is where cartons are unitised ex cool store and at overtime rates. Similarly unitised Scoresby tray packs also cost approximately 82¢ per bush. with carton costing 42.5¢, trays 22¢, unitising 14¢ and wrapping top layer 3.5¢. As the Scoresby unit includes vertical supports and a lid which cost approximately \$1.20, the labour component is higher because of the supports. Like the cell pack, it may be higher if a separate unitisation programme after precooling was used. At present the direct incentive to unitise is only approximately 4.5¢ bush. freight reduction, but there are indirect incentives associated with loading rates and discharge conditions that cannot be costed easily. During 1972 the loading rate differential given to units was approximately 9¢/bush.

An important aspect of unitisation is the development of stacking patterns that enable cartons to be unitised off the packing line and then efficiently cooled in unitised form. Martin, Meizitis and O'Loughlin (unpublished data) found that the 'Pencrate' unit which consisted of eight cartons per layer without any internal air spaces between cartons had a half cooling time of 178 hours for its slowest carton. By comparison the Scoresby unit on 42" x 46" pallet had a satisfactory half cooling time of approximately 50 hours. Parsons, Mitchell and Mayer (1970) developed design cooling curves for forced-air

cooling of unitised pallet loads of plums and pears in cartons. Several stacking patterns, vent sizes and types of fruit were evaluated at air flow rates of 0.1 to 1 c.f.m. per pound of fruit.

Although shipping companies and the Australian Apple and Pear Board have agreed to aim for the 40" x 48" x 72" module, the only unitised packs excluding bulk bins that meet this are the half bushel crated cartons developed by Blue Moon Pty. Ltd. and Export Packers Pty. Ltd. If the module was to be rigidly enforced, the results would be similar to those obtained by Chapagas and Anthony (1971). They studied apples, citrus, lettuce, potatoes and table grapes in shipping containers, railcars and highway trailers. They concluded that the 40" x 48" pallet does not efficiently utilize the loading space in existing U.S. refrigerated transport vehicles and existing packages don't efficiently utilize the pallet area.

A committee representing the member countries of O.E.C.D. has adopted standard pallet dimensions of 1000 x 1200 mm and 800 x 1200 mm. The committee also adopted the external carton sizes of 60 x 40 cm, 50 x 30 cm and 40 x 30 cm because these fit the two pallets without any waste space. Hence, to comply with these dimensions for long voyages, internally vented cartons would be necessary. This in turn could cause problems with venting internal fitments such as trays and also does not permit stacking supports within the unit.

Mallison and Stokes (1970) examined the feasibility of using a 50 x 30 mm cell box for exporting McIntosh and Golden Delicious. They found that it would cost more per carton to pack and ship than using their standard cell pack for each variety. The 50 x 30 cm carton when used for cell packs required the use of unsightly 'air' or filler part cells.

Using place packed citrus, Peleg and Orlowski (1971) developed a mathematical computer search model for obtaining all feasible container dimensions and their stacking patterns on a pallet of given dimensions.

Experimentation with unitisation has not been restricted to fruits, as Carlsen, Freeman and Breakiron (1971) studied the feasibility of selected systems for unitising 10lb bags of potatoes. This study indicated the potential for reducing costs by using the continuous bag method of unitising consumer size bags of potatoes. These were highly adaptable to unitisation making compact, stable palletised units which allowed good use of transport and storage space. The authors believed this continuous bag method of unitising consumer size bags may reduce costs of handling commodities such as onions, oranges, carrots and grape-fruit.

The A.P.M. palletising chart should prove useful for palletisation or unitisation locally and interstate on the 46" x 46" pallet. The chart indicates the most efficient stacking systems for fibreboard cartons from 8" x 6" to 24" x 18" on this pallet.

Hence, at present, there is active experimentation to establish the best means of unitising existing packs of a range of fruit and vegetables. Once unitising techniques have been established, more attention can then be diverted to finding packages that will fit the internationally acceptable 1200 x 1000 mm pallet. The use of 140/160 cell packs and Scoresby tray packs for unitised apple exports is only a temporary phase providing the industry with a means of unitising their exports. However, ultimately, packs will have to be developed for the 1200 x 1000 x 1850 mm module and to also comply with metric weights and volumes. In view of the proposed modifications to packs for unitisation, it will be difficult to establish the one pack for both containers and unitised shipments. In fact recent developments suggest that there are some reasons for having distinctive packs maximizing the advantages of each form of transport.

Containerisation

The introduction of containerisation into the Australia-U.K. trade has transformed the transport of a portion of Australia's apple and pear exports. The Australia-U.K. shipping lines through two consortia - Overseas Containers Ltd. and Associated Container Transport - have pioneered the complete system which commenced in 1969 using special container ships. The main advantages are greatly reduced cargo handling with correspondingly less damage to cargo, much better protection against pilfering and quicker deliveries. Perhaps its greatest feature is the regularity of sailings and (based on Western Australia's figures for 1971-72) a reduction in freight and handling charges totalling 50¢/bush. over conventional shipping and handling. One of its disadvantages is the size of a container (20' x 8' x 8') which limits its progress into the marketing chain before it has to be unloaded manually. Unsuccessful trials from Western Australia in 1969 using pattern packed apples in containers indicated that protective packaging is still required for this method of shipment.

After two years of research, Middlehurst, Parker and Coffey (1969) detailed thermal performances of insulated containers and methods they used to establish rates of heat leakage. Considering air flow within a container, they found that a considerable amount of air flowed up the gaps between cartons

even in a supposedly tight stow and this air adequately removed heat from the fruit. The air flow depended on the size of the carton and the stacking pattern.

Fruit temperatures were monitored in ten I.S.O. insulated containers of apples and pears in normal export packages during export from Australia to U.K. by Hall and Coffey (1970). Cooling rates in the containers were faster than in conventional ships, while equilibrium temperature differences between fruit and delivery air and also spatial differences in temperature were smaller. The results also suggested that cartons may be safely block-stowed in such containers. Because of greatly reduced manhandling of the cargo, bruising of the fruit and damage to the cartons was also much less than normally experienced.

According to Hall (1972), an experimental shipment to U.K. in 1970 indicated satisfactory rates of cooling of oranges in one-bushel wirebound boxes carried in containers both with and without vertical dunnage. However, it appeared that fruit pre-cooled before loading was somewhat fresher at discharge. In a smaller trial shipment in I.S.O. containers from Melbourne to the U.K. in 1969, unwrapped Valencia oranges in cartons stowed with vertical laths every second row carried as well as wrapped fruit in wirebound boxes block stowed.

The most striking development with the shipment of apples in containers has been the advent of the Scoresby tray pack as designed by Pegg (pers. comm.). Starting with the Standard Tray Pack carton, he reduced its height by $5/8$ " and width by $1/16$ " to obtain a stow of 518 ($7 \times 7 \times 10$ plus one row 7×4 across the container). By using the diagonal packing system, he was able to put larger fruit into each cup in the tray. As the larger fruit sits higher, one tray is omitted, thereby reducing costs. The main advantage of the Scoresby tray pack is that 518 can be stowed in each type of container instead of 414 to 444 standard traypacks since freight rates have been negotiated on a container load basis.

In export trials, Pegg (1970) had average nett weights of $42\frac{1}{2}$ lbs for Granny Smiths in Scoresby tray packs with an overfill of $1/2$ " at packing for wrapped fruit. He found that bruising in Scoresby tray packs was similar to that in standard tray packs.

More recently Pegg (1972) has proposed the Australian Pear Carton (I.D. $14 \frac{3}{4}$ " $\times$ $11 \frac{3}{4}$ " $\times$ $10 \frac{7}{8}$ "). The carton was designed to give an improved stowage of pear packs (686 instead of 632) in a container as well as fitting the 40×48 " pallet. The same carton could be used for apples and even citrus. In a container the use of this carton would mean a freight saving of approximately 30¢ per carton. Preliminary observations on its use for unitising by O'Loughlin (unpublished data) indicated that it was unstable due to the carton's small base.

The future development of container shipping will depend on how well the problems can be overcome. In spite of the results from early experiments on cooling within containers, there have been some problems with temperature control. In some instances it can be attributed to faulty refrigeration controls (e.g. frozen produce) and others to inadequate precooling aggravated by bad dunnaging. The latter problem is likely to increase with the freight rate-per-container resulting in a tendency to stow the container as tight as possible. It may be necessary to control stowage patterns and dunnage by regulations to ensure satisfactory air flow. Methods of loading and unloading fruit from the containers could be improved - at present the best is to use a platform on rollers within the container with two men stacking the cartons onto a pallet.

Bulk Bins

The bulk handling of fruit in the orchard originated in New Zealand in 1952 and was rapidly implemented in New Zealand and Australia. Other countries have since adopted bulk handling in the orchard and have carried out a considerable amount of research into the design of bulk bins, the equipment required and the effects of bulk handling on the fruit. Although originally introduced for pome fruits, the application of bulk handling in the orchard has been extended to a wide range of fruits and vegetables.

The original shipments of fruit overseas in bulk bins was reported by Walker (1959). The results were very favourable, but shipments in bulk did not increase as had been expected until 1968. There were two main reasons -

- (1) Facilities for handling bulk bins in British warehouses were limited, and
- (2) Selling opportunities for Australian fruit in bushel containers continued to be buoyant.

In 1968, over 7,000 bins were exported from Tasmania and during 1972 the figure rose to just over 13,000 bins from Tasmania and nearly 7,000 from Western Australia.

Walker (1969) examined the possibilities of filling export bins in the orchard instead of in the packing shed. Wherever it was possible to make direct comparisons, the bulk bin fruit invariably graded out better than fruit shipped in orthodox bushel packs. Walker estimated that the net saving to be made by shipping and landing orchard-filled bins in English warehouses and subsequently grading and

filling the fruit into retail units could amount to 65¢/bush. Richardson (1971) concluded that orchard sorted fruit was the most profitable fruit in a series of trial shipments to the U.K., comparing orchard-sorted fruit in bulk bins with fruit that was sorted and graded by a local packhouse and then exported both in bulk bins and bushel cell packs.

In spite of the economic advantages of orchard filled bulk bins, their use in 1972 accounted for approximately 100,000 bushels of apples sent overseas from Tasmania and a similar quantity from Western Australia. The use of orchard filled bulk bins for export seems to be restricted by -

- (a) The relatively narrow fruit size range requested in bins.
- (b) The limited nature of sorting possible for coloured varieties and elimination of other faults e.g. russet on Sturmers.
- (c) Climatic conditions.

The inclusion of too much sub-standard fruit would result in a poor packout overseas - hence freight would have been paid on low value fruit.

The other significant development in the use of bulk bins for export took place in Western Australia. In 1971 Hardisty (pers. comm.) found that the cost of the 'Clemar' bin (a modification of the bin described by O'Brien (1960)) could be halved by using unseasoned smooth sawn hardwood. Prior to the 1972 season, the West Australian industry was advised that no shipping space suitable for Clemar bins could be guaranteed. This prompted the development of the container bin by Hardisty and Melville (pers. comm.). Its external dimensions are 44" x 43" x 40" and it was designed for orchard sorted fruit. Cost savings of approximately 65¢/bush. over container shipped Scoresby tray packs, have been claimed for the container bin which was used extensively (3,700 bins) in W.A. during 1972.

An important aspect of handling fruit in bulk bins has been to ensure adequate ventilation. Mellor, Hall and Martin (1962) reported that bins with 10% of the floor vented cooled as fast as packed standard apple boxes in free space. Patchen and Sainsbury (1962) agreed with this but concluded that side ventilation was as effective in some circumstances. They considered that pallet based bins with fibreboard liners probably should be provided with sufficient slots to bring the free area of both bottoms and sides to more than 5%. Martin (pers. comm.) found that using a polythene liner inside a bin slowed down the rate of cooling considerably and that there was a good case for filling with pre-cooled fruit. From his

observations on commercial handling of the well based 'Unibin', Arnold (pers. comm.) concluded that restricting the air circulation by liners was more detrimental than the slight increase in bruising that resulted from not using liners.

For conventional shipments from Australia, the Australian Apple and Pear Board has stated that bins must stack two or three high to fit the standard module of 40" x 48" x 72".

In view of earlier overseas work by O'Brien (1960) and Smith and Roach (1962), Richardson and O'Loughlin (unpublished) conducted export trials with well based 'uni bins' (I.D. 20 1/2") and Clemar bins (I.D. 29 1/2"). They found no commercially significant differences between bin types with respect to bruising, despite the effects of increasing depth on bruising in each type. Further trials are in progress with lined and unlined bins of varying depths.

The use of bulk bins for transport locally or interstate has been limited to outlets such as canneries for processing, and chain stores which require prepacking just prior to sale. The development of returnable bins on a hire basis has been another interesting aspect of the application of bulk bins to local and interstate trade in fruit and vegetables.

Future work on bulk bins will centre on ways of extending their application to both new fruits and vegetables, as well as fruits that are already being shipped in bins. For apples, it might be possible to economically increase their usage for orchard filling for export, especially in good quality crops.

Returnable and Re-Usable Packages

In a sense, the adoption of returnable plastic packages for Australian markets would be akin to the radical change involved in the export trade by the introduction of containerisation and unitisation.

The possibilities and problems with returnable plastic packages for local and interstate handling of fruit and vegetables has been considered by Newman (this Conference). The main advantages of such a system would be uniformity (at present there are 44 different packages registered for use in the Melbourne market), reduced costs, and improved handling. The main disadvantages would be high initial costs as well as difficulties with returnability and accounting.

Attempts have been made to export fruit to U.K. in re-usable crates and bins. The basic idea has been that although they are initially more costly per bushel than disposable bins, cartons, cases etc., they have a market value overseas. Hence the nett cost to the Australian grower is lower than using disposable packages.

The only two successful examples are Sainsbury crates and Unibins, each of which is going to a particular importer who uses that particular type of crate and/or bin. The future of the crate exercise is in doubt, as the freight disadvantage tends to offset the resale value. Under most circumstances, the weak link seems to be organizing the sale of bins, pallets, boxes, etc., in U.K. to get a worthwhile return to the Australian grower. Perhaps the most facetious but relevant comment on the possibilities of reusable packages and pallets in U.K. was that although pallets were unsalable they should be standard size to fit the pool of standard pallets!

Air Transport

Generally speaking, the more perishable a commodity, the greater is the potential advantage of air transport. In fact, the main advantages of air transport are lower packing costs and fast delivery permitting highly perishable fruits and vegetables to arrive in fresh condition on highly competitive markets.

At present New Zealand is exporting increasing amounts of fresh strawberries and Kiwi fruit (Chinese gooseberries) by air to the Sydney market. Californian strawberries, New Zealand cherries and numerous other perishable fruits and vegetables are available on European markets due to the rapid handling possible by air transport.

To enable the airlines to deliver superior products justifying the higher cost of air transport, Maxie, Mitchell and Sommer (1966) considered that a number of facilities and techniques for maintaining high quality were necessary. These centred around maintaining product temperature during all stages of transit where possible and designing pallets and packages for air transport.

It would be far preferable to have specially designed aircraft for transporting fruit and vegetables. However, it is possible that airlines will be searching for cargo (especially back freight at reduced rates) with the advent of larger aircraft and this could hasten the greater use of air transport for fruit and vegetables.

Handling Packages Individually

Since the early 1960's, there has been a gradual change from wooden cases to fibreboard packages for most fruits including apples, pears, citrus, bananas and some fresh vegetables. This change has increased the protection afforded to contents, but produced handling problems under some conditions.

The use of the flat sided cartons has made cooling of packed fruit more difficult in many situations. However, as they were being introduced, workers such as Sainsbury and Schomer (1957), Olsen, Patchen and Schomer (1960), and Hall (1962) showed that freely exposed cartons of apples and pears cool about as fast as freely exposed wooden boxes of fruit. One of the problems with cartons therefore is stowage to ensure adequate air flow around each package.

Considering markets that can't readily handle containers, units or bins e.g. Hong Kong, Singapore, and the existing Sydney market, the main emphasis has been on improving the handling of fibreboard, especially under moist conditions. This has led to systems of water-proofing to give high 'wet-strength'. Since wax dipped cartons were introduced for the transport of bananas, their use has extended to other fruits and vegetables. On a recent visit to Sydney markets, wax dipped inner cartons were being used for several fruits and some vegetables.

The use of a telescopic carton with a wax dipped inner overcomes the problems of using a fully wax dipped R.S.C. carton as tried by O'Loughlin and Walker (1969). They found that wax coated cartons were no better than unwaxed cartons. However wax dipped and plastic cartons had sufficient stacking strength for South East Asian markets.

The plastic cartons presented problems with condensation in these trials and also in shipments to the U.K. by Peggie (1970). However, as the plastic cartons were too expensive, their use for fruit has ceased.

The other major development in individual packages in Australia has been the use of tight-fill packs to reduce costs. Following the early work by Mitchell - *et al.* (1965), Schoorl (this Conference) has applied the principle to tomatoes grown in Queensland. At present tight fill tomatoes account for one third of the tomatoes packaged in Queensland. Schoorl (pers. comm.) is also working on tight-fill packing of pears, bananas and apples.

Export trials by Balodis (1969) to improve the stowage of cell pack apple cartons by building up the nests to give a one-height series indicated distinct disadvantages. His recommendation was for a modified two-height carton series and that shipping trials for comparing minor modifications to the cell pack be discontinued.

As a result of his own experience and that of others, e.g. Chapman and O'Loughlin (1967), O'Loughlin and Walker (1969); Balodis (1971) concluded that a compression test under standard laboratory conditions will not assess the bulging tendency of

fibreboard fruit packs under service conditions. He developed a laboratory test schedule based on information collected in overseas shipping trials. The proposed schedule incorporated the special conditions encountered in temperate zone and tropical markets.

In a consideration of the forces acting on a fruit package, Schoorl (this Conference) reviewed the effects of load forces, impacts, abrasion and vibration. He considered that the testing of packages under a wider range of frequency and acceleration would enable much better design of packages if combined with package handling data and information about the fibreboard carton strength required.

For high quality apples, pack handling from tree to consumer as studied by Hanna and Mohsenin (1972) could be feasible. This concept involves the packaging of apples in the orchard into small count polystyrene packages so that the fruit is protected from damage before leaving the orchard. Its use would be limited to evenly sized crops of high quality fruit for premium markets.

Future Developments

The development of containerisation and unitisation together with the possibilities of returnable packages and air transport, indicate radical new approaches to the handling and transport of fruit and vegetables. The advent of the Scoresby tray pack has made a break with the traditional approach to packing apples. In a sense, the presentation of fruit and vegetables has been freed from the limitations of traditional pattern packs in wooden cases. How much further we can go is open to debate. Future developments should be aimed at reducing (or holding) package and transport costs while still providing sufficient protection for the contents.

It should be possible to develop further specialized packs and economies for unitisation and containerisation as well as devising further applications for bulk bins and returnable packages thereby maximizing the advantages from each form of transport. It would seem that the advantages of pursuing specialized packs to the limit outweigh the gains from having a general purpose pack that is suitable for different methods of handling. Hence the future could provide a limited number of packages specifically related to the method of handling and transport instead of the present assortment of general purpose packs. If possible, preference would be for slight variations in components (e.g. wax dipped Scoresby cartons for South East Asia) rather than separate packages for alternative purposes.

One of the disadvantages of the swing to fibreboard packages during the sixties has been the resulting multiplicity of package dimensions and types. The advent of metrication is a great opportunity to increase standardization with a view to holding costs and simplifying marketing.

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Discussion:

It was agreed that the new technology in packaging and handling has been rapidly adopted by industry because it was specifically aimed at reducing costs and has done just that. In 1972 40 per cent of the apple exports from Tasmania were unitised where main cost savings were concessions in handling and freight charges. Export in bulk bins should be extended as a real cost saver, provided good arrangements can be made for repacking and marketing.

DEPTH OF FRUIT IN ORCHARD SORTED EXPORT BULK BINS

B.D. Richardson*

Introduction

The overall height specification of the I.S.O. container and of the unit module for shipment of palletised apple packs has placed certain restrictions on the practicable overall height of export bins. In 1971 and 1972, experimental shipments to the United Kingdom were conducted with orchard sorted fruit to find the limit of depth for Tasmanian varieties so that future designing of bins may be on a sound basis.

Trial 1, 1971

Standard commercial bins of three internal depths were compared under typical commercial handling conditions from orchard to U.K. packhouse. Results are confounded by type of bin structure in relation to depth effects. Table 1 shows the treatments and the percentage of unbruised fruit, i.e. number 1 grade but based on bruise only, which were recorded by experienced British packhouse staff.

Table 1: % of Unbruised Fruit Graded Out of Bins

<u>Common Bin</u> <u>Name</u>	<u>Internal Depth</u> <u>(cm)</u>	<u>Variety</u>		<u>Fruit with</u>
		<u>Jonathan</u>	<u>Golden</u> <u>Delicious</u>	<u>Stalk</u> <u>Punctures</u>
		(%)	(%)	(%)
Unibin	51	88	84 *	1.5
Freightmaster	66	88	73 *	2.2
Clemar	75	87	79 *	2.3

*Statistically significant differences between bin types.

There was only a small percentage of fruits in all bins with moderate-to-severe bruises. The fruit was removed evenly over the whole bin during recording and layers of approximately 8 cm depth were calculated from the fruit numbers in each bin to get percentage increases in bruising with depth (Fig. 1(a),(b)).

Discussion

Regression lines, calculated on the increase in slight bruising with depth (Fig. 1(a), (b)) were significantly sloped in all bins for both varieties. In the second from bottom layer, up to about a fifth of Jonathan apples and a third of Golden

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Delicious apples were slightly bruised. The contribution to this bruising made by the orchard factor of emptying picking bags and moving fruit about during sorting cannot be separated from the effect of depth alone. A factor which adversely affected the overall outturn of the Freightmaster bin was the damage to fruit on the unlined floor. By contrast, the fibreboard liners in Clemar bins overcame this problem almost completely.

Overall, all bin types carried the fruit well while the importing country is prepared to accept a percentage of slightly bruised fruit, but its significance in the future when quality is all important is unknown. The commercial significance of the statistical difference between bin types for Golden Delicious could not be assessed for the same reason. However, the worst bin, the Freightmaster, was removed from the trade by the manufacturer in 1972.

1972 Trial

Greater emphasis during the 1972 trials was placed on the actual effect of depth by the following modification during orchard filling. Waste fruit was thrown down by the pickers, and assistant staff helped them discharge fruit into the bins with maximum care. The fruit was not further sorted in the bin and range of bin depths was extended. A vertical-board construction was incorporated (the Clennett bin) to compare with the horizontal boarding on the Clemar types and the effects of fibreboard liners were more closely studied.

Results

Table 2 shows the percentage of unbruised fruit in the bins -

Table 2: Percentage Unbruised Fruit in Bins at Examination
in U.K. Packhouse

<u>Bin Type</u>	<u>Internal Depth (cm)</u>	<u>Variety and %</u>		
		<u>Golden</u>	<u>Delicious</u>	<u>G. Smith</u>
A Clemar hardwood lined	75	97		99
B " " not "	75	95		97
C " softwood "	75	95		97
D " " not "	75	91		93
E " hardwood "	45	97		99
F " " "	105	91		93
G Clennett hardwood lined	75	95		97
H " " not "	75	91		96
J Unibin hardwood lined	51	97		99
K Unibin " not "	51	96		99
L " " bottom only				
	lined 51	95		100

Again there was very little class 3 fruit (moderate to severely bruised) in the bins.

Analyses were carried out on three nominated comparisons within the 11 treatments.

- (a) - Treatments A, B, C, D, G, & H, J and K to compare commercial bin types and any effects of liners.
- (b) - Treatments J, K, and L to study the effect of liner in the shallow bin.
- (c) - Treatments A, E and F to study the specific effect of depth within the one type of construction.

Again the data was summarized in layers of approximately 8 cm of depth (Fig. 1(c), (d)).

Discussion

Overall there was considerably less bruising than in 1971, presumably at least partly due to the more careful handling during filling in the orchard.

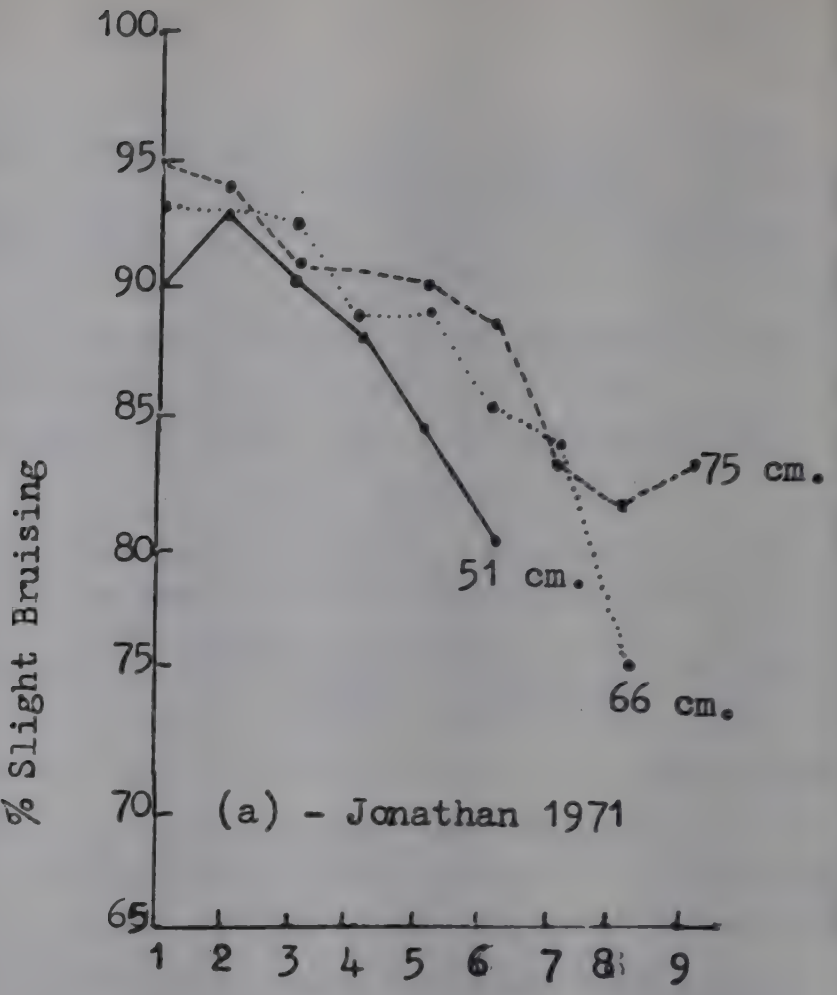
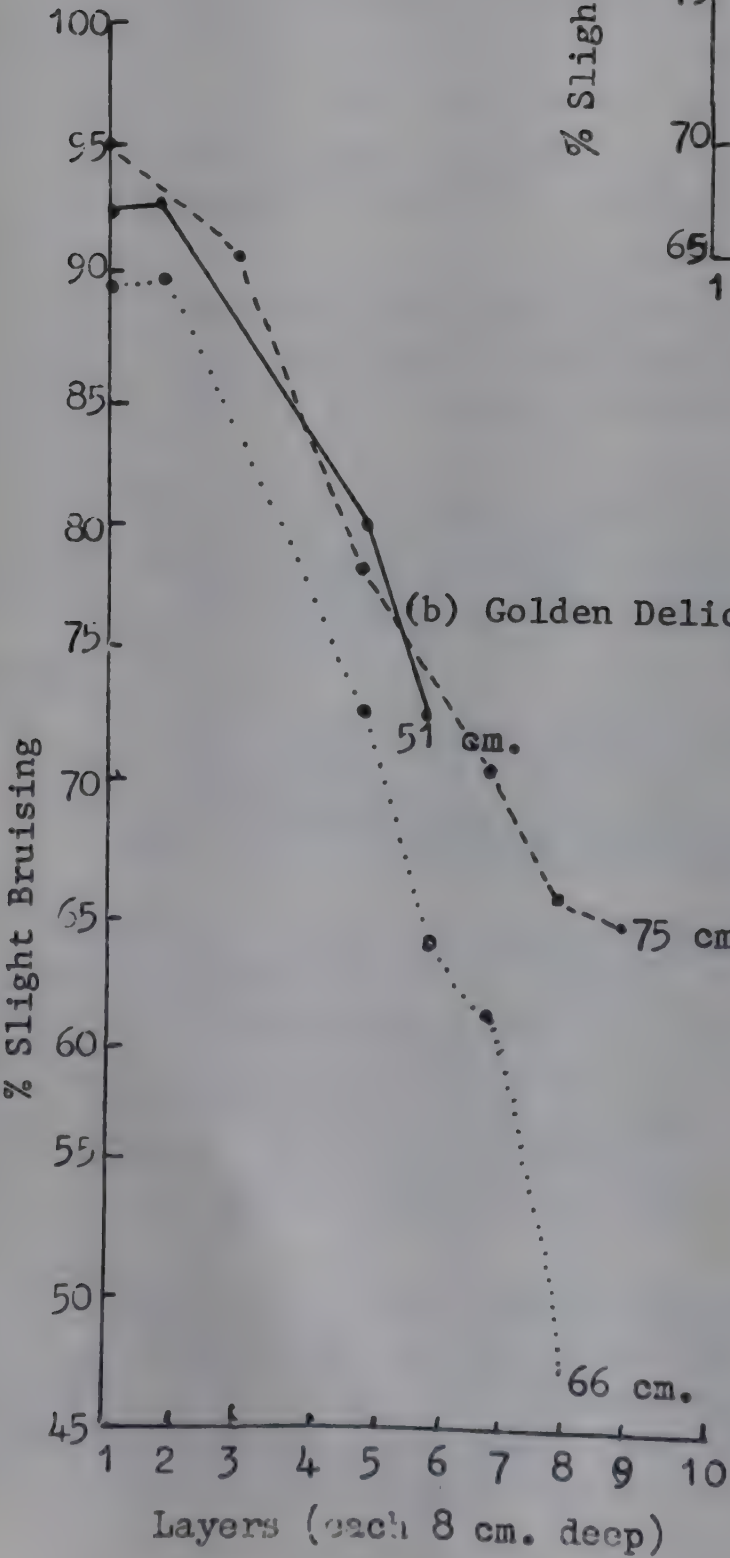
Trial (a) - Despite small differences between lined and unlined bins over all types and varieties the differences were significant ($P = 5\%$ for Golden Delicious. $P = 1\%$ for Granny Smith).

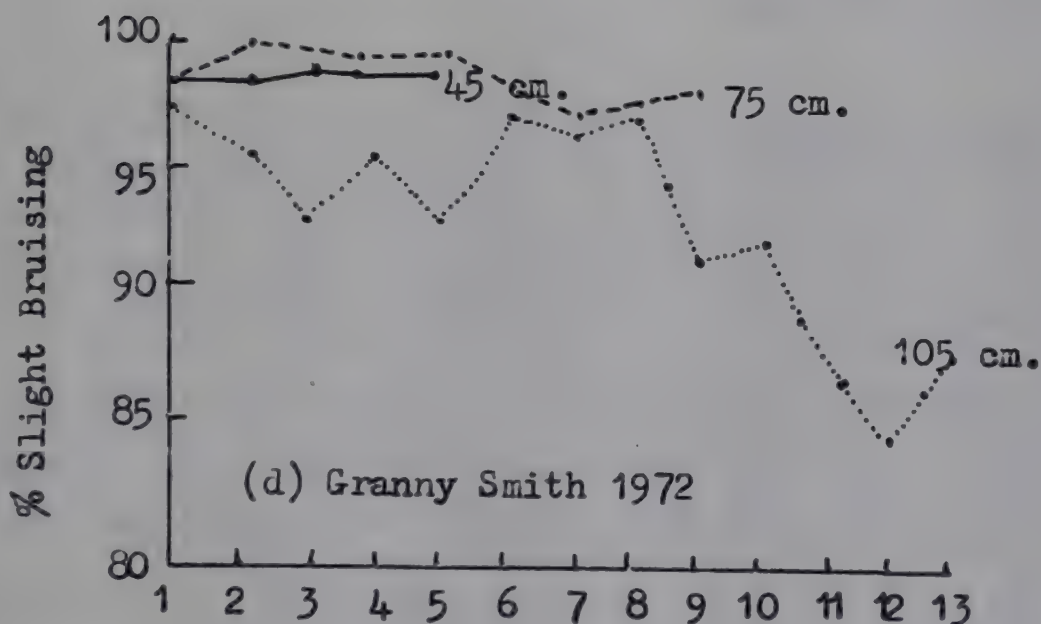
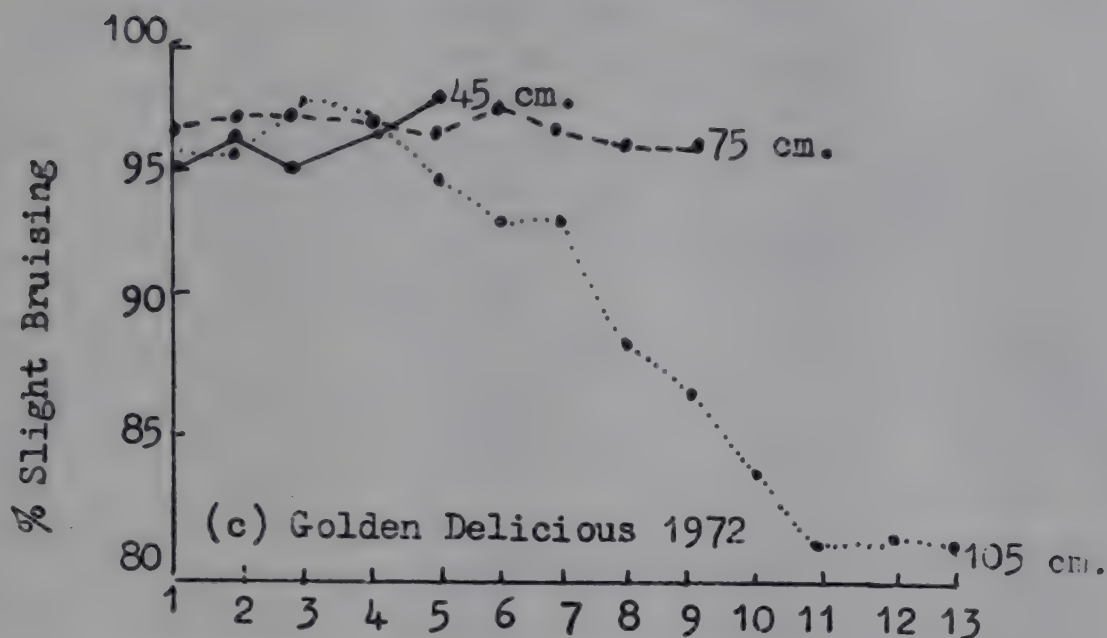
Some of the value of liners was clearly due to the bottom section protecting the fruit against damage on the floor of the bins. There were significantly lower percentages of bruised fruit in the bottom layers of lined 75 cm deep bins.

The relatively shallow Arnold bin gave the best overall result although it was not significantly better than the Clemar bin for either variety. The commercial importance of the extra 2-3% slight bruises in the Pine and Clennett bin compared with the accepted standard "Clemar" bin of the same depth, was again questionable.

It would remain for more extensive commercial trial shipments to determine if the difference is maintained or extended for the Pine and Clennett bin. The latter was constructed of relatively thin vertical boards and was without corner posts. This permitted an extra 27 kg of apples to be put in the bin, representing a potential saving in transport space per bushel. Also liners were responsible for the loss of about half a bushel capacity.

Trial (b) - There was no evidence to show that a liner was needed in the shallow Unibin, the effect of the hard timber on the bottoms of the bins not being demonstrated as in 1971. The different conditions under which the trials were conducted make this comparison dubious as indeed any comparisons of the two season's results.





Figures 1(a) and (b). Percentage unbruised fruit in successively deeper layers in orchard sorted bulk bins - 1971 experiment. Internal bin depths shown on each line.

Figures 1(c) and (d). Percentage unbruised fruit in successively deeper layers in orchard sorted bulk bins - 1972 experiment. Internal bin depths shown on each line.

The general difference in slopes between Figures 1(a) and (b) compared with Figures 1(c) and (d) is possibly associated with the different handling conditions during harvests for 1971 and 1972 (see text).

Trial (c) - Figure 1(c),(d) show the change in percentage slight bruising in layers. It was obvious that increasing internal bin depth beyond 75 cm resulted in a real increase in bruising, although again, there was little severe damage to the apples in the lower layers. The average increase in bruises was not very great (approx. 5-7%) when the overall figures for the 105 cm deep bin were compared with the shallower models.

The module for shipping apples on pallets is 183 cm high and there is no obvious reason to make bins deeper than 75 cm internal (91½ cm external) for that method. It appeared that this was about the depth at which bruising begins to become more significant. However, there could be some justification for a bin slightly deeper than this to fit two-high into I.S.O. containers. The extra bruising overall due to a further approximately 10 to 15 cm of depth would again depend for its significance on the commercial importance of slightly bruised fruit on arrival overseas.

Conclusions

- (1) Considerable differences in the amount of bruising of orchard sorted bulk bins occurred in the two seasons 1971 and 1972, presumably due to conditions of harvesting, filling and sorting the experimental bins. No investigation has been made of the possible interaction of bin depth with methods of filling and grading the fruit.
- (2) Slight bruising occurred more in the deeper layers of the commercial bins used in 1971 but it was not until fruit was over 75 cm deep as in 1972, that the straight effect of depth came into possibly commercial importance.
- (3) On today's market in the United Kingdom, the 75 cm deep bin would appear to be the most practical if no resales are available after the fruit has been removed.

Discussion

Although the lining of bins significantly reduces bruising this advantage is less than the disadvantages of slower cooling and interference with water dumping in the U.K. However, in Western Australia, liners were used to allow of cheaper timber construction of the bins. Experience with bins in W.A. has shown that Granny Smiths bruise less in handling after a few weeks storage. The cost of packaging in the U.K. is little more than half the cost in W.A. and export in bins will increase considerably from that State.

IMPLICATIONS OF RETURNABLE PACKAGES FOR TERMINAL MARKETS

B.J. Newman †

Before discussing the implications of a change in the current methods of handling fruit and vegetables at our terminal markets, it is wise to establish that a change is needed. A number of questions need to be answered.

Is the present handling of produce at terminal markets satisfactory? If the answer to this question is no, then what changes do we propose to improve the situation? We must then ask, what are the implications of such a scheme to the various links in the production chain?

That there is a need for some improvement in the system of handling is easy to establish. On the Melbourne market alone there are some 44 different containers registered for use. This list includes wooden boxes and crates, fibreboard cartons, jute sacks, net bags and plastic bags, all of various sizes, shapes and capacities. Many of the sizes between containers vary by only a fraction of an inch, but this is sufficient to make loading and interstacking very difficult. To complicate matters further there is a range of produce that is sold through the various terminal markets without any container at all. Cabbages, cauliflowers and pumpkins would often fall into this category.

To overcome these problems we are proposing a system of uniform, plastic boxes, built on a modular basis in a range of sizes that will interstack and will nest, when empty, within their own size range. To reduce per use cost such a container would need to be reusable.

At this stage a range of three containers is envisaged with capacities of about 1/2 bushel (20 litres), 1 bushel (40 litres) and 1 1/2 bushels (60 litres). These three sizes would have uniform top and bottom dimensions, their capacity varied by changes in height.

The dimensions of the Australian standard pallet 46" x 46" (120 cm x 120 cm) becomes the overriding factor in determining the top dimension of the containers.

The following advantages are some which are claimed in support of the proposal:

- * There would be an economic benefit to producers and the cost per market trip would be substantially reduced compared with containers currently in use.
- * Plastic boxes are easy to clean and hygienic.

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- * They can be made to give a very stable stack incorporating a range of sizes. They can be made to nest when empty to facilitate return freighting.
- * Being rigid and provided with plenty of hand hold they would be easy and safe to handle.
- * Plastic materials are resistant to heat, cold, light and water. Wet produce and rain will not affect their strength.
- * No making up or maintenance costs would be involved.
- * Ventilation and drainage can be readily provided to improve cooling rates or allow the hydro-cooling of produce.
- * Vegetables such as cabbages and cauliflowers, now handled loose, could be field trimmed and handled in boxes. This would eliminate a major problem of garbage disposal at terminal markets.
- * A rigid box of constant tare weight allows loose filling rather than packing. Produce could then be sold on a minimum net weight basis. This would greatly reduce production costs.
- * Loose filled, open topped boxes can be easily inspected by both Departmental Inspectors and buyers.
- * By attaching printed advertising material produce could be attractively displayed to the public without additional handling.
- * The change to metrication would assist in the conversion to sales on a weight basis rather than volume.

There are also a number of disadvantages concerning the proposal and these include the following points:

- * High initial capital outlay to purchase containers and set up the scheme.
- * Major distribution centres would need to be set up in conjunction with terminal markets to clean and reorganize containers.
- * Some form of debit/credit system is required. This will be difficult where there is a predominantly growers' market such as Melbourne.
- * An attractive box with many potential uses could lead to a large loss factor.
- * Unless there is wide acceptance amongst producers, wholesalers and retailers the scheme would be difficult and costly to operate.

- * A uniform box may not suit all produce. Specialized liners and trays may need to be developed.
- * Returnability may lead to some problems for both producers and retailers.
- * Fibreboard especially is bio-degradable, plastic is not.

The implications of any change to the handling system at terminal markets will be in the context of these advantages and disadvantages.

There are four involved groups that must be considered. The implications of the change will be different for each group and the advantages and disadvantages of such a scheme will be given different priorities by each group.

The four groups to be considered are:

The producers
The wholesalers
The retailers, and
The market authorities.

The implications to these groups can be listed in order of importance and can be termed either favourable or unfavourable. These can be summarized as follows:

	Favourable	Unfavourable
Producers	1. Cost reduction 2. Improved produce handling. 3. Uniformity 4. Durability 5. Loose fill - weight sales	1. Returnability 2. Accounting ☐ agent ☐ buyer 3. Loss factor 4. Storage space 5. Capital investment
Wholesalers	1. Uniformity 2. Improved produce handling 3. Durability 4. Produce protection	1. Returnability 2. Accounting ☐ producer ☐ buyer
Retailers	1. Uniformity 2. Produce protection 3. Convenience and inspection 4. Weight guarantee	1. Returnability 2. Deposit 3. Accounting ☐ producer ☐ whole-saler 4. Storage 5. No second use (orders)

	<u>Favourable</u>	<u>Unfavourable</u>
Market	1.Reorganization	1.Reorganization
Authorities	2.Garbage reduction	2.Increased cost
	3.Palletization	3.Storage and cleaning
	4.Uniformity	
	5.Hygiene	

Of the factors mentioned in this list uniformity would seem to be one of the most favourable implications of such a scheme. From the individual producer's point of view and from an industry point of view a system of uniform containers will reduce many of the problems and much of the confusion. Improved protection of the produce through to the consumer will result in a lower wastage factor and higher quality.

The retailer stands to gain substantially from the proposed scheme. It will be possible to buy produce in any order, stack it without damage, tomatoes on the bottom, potatoes on top and peaches in between, if necessary. The system will mean greater convenience for the retailer when buying at the market.

It is also a vital factor in a scheme of this type that there should be uniformity between the various States involved in an interchange of fresh fruit and vegetables. In fact, without this uniformity the scheme will have no chance of success. With the type of perishable produce we are dealing with it is often necessary to 'play the market' and agents are continually diverting produce from one terminal market to another. Ideally this must be done quickly and with as little handling as possible.

If a uniform system of containers operates on a national basis then produce can be interchanged between the various terminal markets in the same containers. Empty containers returned to the market will be re-injected into the system at that point.

At all costs the introduction of containers of slightly different shape or size into the individual States must be avoided. The returnability factor appears to be the one that could become the greatest problem. The work involved in accounting and recording such a system is substantial and the problem is magnified where we have a substantially grower oriented market.

In terminal markets where most or all produce is sold through agents the problem may be more easily overcome. Agents already operate accounting and recording systems that could, for a fee, cope with the additional administration necessary.

Ideally a major company may put up the necessary capital to set up and administer a scheme. Boxes could then be hired to growers at a minimal charge per week or per year. From the growers' point of view, purchase would be cheaper as the boxes are expected to have a life in excess of 5 years at the

rate of 10 to 15 market trips per year. However, the generation of the necessary capital to enter such a scheme may cause difficulty to many producers.

The consideration of implications and factors involved in such a scheme inevitably leads to a consideration of the methods of introducing such a scheme to the industry. Given that there will be no compulsion - but the scheme's adoption will be one of free choice this then becomes a very major extension problem.

I believe the classic steps in the adoption of any innovation will need to be followed very carefully by any organization attempting to introduce such a scheme. The success of such an undertaking will be subject to the various steps being achieved by a diminishing number of the total individuals involved in the change.

The following stages must be accomplished in this order and with about the following percentage of each of the four involved groups. This will be the initial stage of adoption.

The innovation stage:

Awareness	.	.	.	.	.	.	.	100%
Interest	.	.	.	.	.	.	.	100%
Evaluation	.	.	.	.	.	.	.	40%
Trial	.	.	.	.	.	.	.	20%
Adoption	.	.	.	.	.	.	.	10%
Continued use	.	.	.	.	.	.	.	5%

Awareness: may be achieved through mass media, newspapers, leaflets, television, radio.

Interest: will naturally follow for most people involved in the industry.

Evaluation: many will proceed further and will gather information. Information must be available through the mass media and through personal channels.

Trial: a percentage of the number evaluating the idea will proceed to the trial stage.

Adoption: if the trial proves satisfactory then adoption will result.

Continued use: will result from continual satisfaction.

It could be expected that from a well-organized, intense extension programme approximately 5% of the total number of people involved would reach the adoption stage. Other factors in the various marketing systems are likely to cause the rapid dropping of the scheme if such a small percentage tried to

operate without continued support from the extension programme. Retailer resistance could be a serious problem. Lower prices for produce presented in plastic boxes compared to that presented in traditional packages would put the innovators at a severe disadvantage.

Therefore it would seem essential that any extension effort will need to be tailored specifically for each of the four involved groups. The different priorities for the various factors must be taken into account when an extension effort is directed toward the adoption of such a change. Adoption by innovators in each of the four groups, about 5% in each group, will then lead to a much faster evaluation by the remaining 95% in each group.

If the presumed advantages are valid then rapid adoption will follow. The result will be a streamlining of a currently confusing and outmoded system of produce handling that should result in substantial benefits to all sections of the industry.

Discussion

The proposed use of returnable packages in Australia was received with considerable interest. A per use cost of 5 - 10 cents per unit might be possible. It was felt to be very important to ensure that the arrangement was acceptable to all parties involved. Experience in Western Australia with returnable plastic crates has been that they are attractive to the grower but not to the retailer. There have been serious difficulties due to opposition from supermarkets. The Victoria committee is not only aware of these problems but is also finding liaison with other States difficult.

CAULIFLOWER PACKING INVESTIGATIONS

B.B. Beattie *, E.K. Leggett * and A.G. Wright +.

Under the auspices of the Sydney Farm Produce Market Authority a Farm Produce Container Research Panel has been formed to undertake research into packaging of fruit and vegetables, especially as it relates to terminal marketing.** In the first place, priority has been given to evaluation of packaging methods for such leafy vegetables as cauliflowers and cabbages, largely because of the problem of trimmed leaves in the markets area. It has recently been estimated by the Chairman of the Authority that the cleaning of the market area and removal of the leaves is costing the Authority \$25,000 annually out of a total cleaning bill of \$42,000.

Background

Cauliflowers are grown for Sydney markets in the Hawkesbury Valley, Hunter Valley and Bathurst districts. In general, the harvesting procedure is to cut the vegetable in the field and load individually onto road transports. No attempt is made to trim leaves from the head, as they afford some protection to the curd during transport. However, it is obvious that leaves left on the vegetable take up much space on the truck (it was found that leaves account for two-thirds the weight of the load).

Some retailers, after buying cauliflowers in the market, trim the leaves off the heads and leave the waste in the market area, before transporting the vegetable back to the shop. Others trim the leaves in the shop, load the waste back on their trucks, and deposit it in the markets when they return the next day. On the other hand, the problem of waste leaves turns many retailers away from purchasing cauliflowers.

With the commencement of operations of the new Sydney Wholesale Markets in 1973, it has been made clear by the Chairman of the Authority that untrimmed cauliflowers will not be permitted in the market. This means that the present practice of bulk transport in full leaf will have to be modified. Accordingly, the research panel initiated a project to examine all aspects of cauliflower marketing.

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**The Farm Produce Container Research Panel is made up of representatives from the New South Wales Department of Agriculture, the National Materials Handling Bureau and the Standards Association of Australia.

Experimental

As a first step, a pilot trial was initiated to evaluate returnable and non-returnable containers which could be used as an alternative to bulk loading of individual heads.

A survey revealed that there was a small number of growers who used other methods, e.g. some consign direct to chain stores or large fruit supermarkets, using returnable wire baskets or bulkbins; several market part of their crop in one piece non-returnable waxed fibreboard containers, (610 mm x 356 mm x 406 mm), made specifically for the purpose. The cauliflowers, handled in these ways, were cut as normal, on the farm but were then trimmed of a percentage of leaves before being packed.

A further survey indicated other containers available which could be suitable for examination. Thus, in the initial pilot trial the following containers were examined:

- (1) Bulkbin (collapsible pallet crate) - wire sides - 1168 mm x 1168 mm x 610 mm.
- (2) Bulkbin - hardboard sides - 1168 mm x 1168 mm x 610 mm.
- (3) Timber box - similar to bushel fruit case - 457 mm x 220 mm x 362 mm.
- (4) Western Australian Nylex crate - sloping sides - 400 mm x 349 mm (top) x 324 mm (height) x 375 mm x 330 mm (bottom).
- (5) Nally collapsible plastic crate - slatted style - 546 mm x 343 mm x 330 mm.
- (6) Hardboard box - constructed by the use of cleates - 508 mm x 330 mm x 305 mm.
- (7) Waxed fibreboard carton - one piece - 610 mm x 356 mm x 406 mm.

In combination with the containers a number of levels of leaf trimming and the effect of curd wrapping in polythethylene* film were examined. Trimming treatments were:

- (a) Full-trim - leaves and stem trimmed from the cauliflower leaving perhaps four to six juvenile leaves around the head with about half the curd showing.
- (b) Semi-trim - enough leaves left after trimming to just cover the curd.

* Glad-wrap (R)

Most combinations of level of trim, wrap and container were examined, in comparison with non-trimmed control units.

Using the Shorts variety, the trial was carried out in May, 1972 from a farm in the Bathurst district of New South Wales. The cauliflowers were picked as they would be under commercial conditions. After packing, the cauliflowers were road transported to Sydney markets the same day and each curd was examined for damage the following morning.

The outturn of the curds from all treatments compared favourably with the outturn of curds from the control treatment. The trial indicated that cauliflowers could be transported without undue damage in bulkbins or other containers when they have been trimmed of most of their leaves. The polyethylene film also appeared to adequately protect fully trimmed curds.

Whilst the containers all transported the cauliflowers satisfactorily, the majority were too small to hold enough heads. Apart from the returnable pallet crate it seemed that a container about the size of the waxed carton at present in use would be the most suitable as a non-returnable package.

It was apparent that a significant amount of space and weight should be saved by trimming the heads to the level of the semi-trim and it was thus concluded that some degree of trimming should be done whatever method of packing and transport is used.

As a second step, data on the physical behaviour (shelf life) of the cauliflowers after they had been transported and marketed, were collected in a trial designed to examine the effects of different levels of leaf trim and overwrap on the weight loss of the vegetable during storage at ambient temperature.

Cauliflowers were harvested from a farm in the Hawkesbury Valley in June, 1972 and subjected to five treatments, viz:

- (1) Untrimmed - control.
- (2) Semi-trim - as before.
- (3) Semi-trim-wrap - overwrapped with polyvinyl chloride film (Resintite (R)).
- (4) Full-trim - as before.
- (5) Full-trim-wrap - wrapped as for treatment 3.

Each head was weighed at full leaf and again after trimming. The cauliflowers were transported to Sydney and stored at ambient temperatures, ranging between 10°C and 20°C. Each cauliflower was weighed daily for 7 days. On the sixth day after harvest those treatments which were not fully trimmed

were trimmed of their leaves and the curd weighed. At each weighing the heads were examined for indications of infection, and for general appearance.

The results showed that cauliflowers which were not trimmed experienced a significantly greater weight loss over the 6 days than any other treatment. There was a 22% weight loss in these, 10% in the semi-trim, 4% in the semi-trim-wrap; 9% in the full-trim and 2% in the full-trim-wrap. The leaf/curd weight ratio of the cauliflowers at harvest was 2:1. It was not possible to empirically distinguish between moisture loss from the leaves and from the curds. It was visually evident that moisture loss came from both the leaves and curds because of the flaccid appearance and flabby touch.

By the fifth and sixth day some curds in all treatments became infected with *Alternaria brassicola*, a field pathogen. All treatments were similarly affected. Leaves began abscising between the second and fourth day on those treatments not fully trimmed of leaves. By the fourth day the leaves and curds became flaccid in those treatments which had not been wrapped. The heads which had been wrapped were still firm and fresh.

In the light of the above pilot trials the next step was to organize a statistically designed trial to be carried out along commercial lines.

The following treatments were involved:

- (1) Control - as before.
- (2) Semi-trim - bulkbin (collapsible pallet crate).
- (3) Semi-trim - waxed carton.
- (4) Semi-trim-wrap-bulkbin (Resinite (R) film).
- (5) Semi-trim-wrap carton.
- (6) Full-trim-wrap-bulk-bin.
- (7) Full-trim-wrap-carton.

The trial took place from a farm in the Hawkesbury Valley of New South Wales. As well as collecting physical data, the times taken for the packing team to complete a treatment were recorded.

All the cartons were transported on the 1168 mm x 1168 mm pallet. There were six bulk-bins and two pallets of 18 cartons in the trial. The cauliflowers were transported to Sydney Markets, a distance of about 56 km, and examined for damage the next morning. The damage rating was on a simple four point scale:

- Nil - no visible bruising;
- Slight - bruising 1-2 cm² area;
- Medium - 2-4 cm² or a number of smaller bruises;
- Severe - larger or multiple bruising.

The damage was extremely light in all treatments and no cauliflower was rated by the judges as being unfit for sale. There was little difference between the treatments in level of damage, the unwrapped treatments generally showed higher damage than the wrapped treatments. The full-trim-wrap treatments, which could have been expected to show higher levels of damage than the other treatments, particularly when packed into wire sided bins, showed comparatively low injury levels. Actual injury levels were: 10% in the controls, 9% in the semi-trim in the bulkbin and in the carton; 4.2% in the semi-trim-wrap in the bulkbin; 5.3% in the semi-trim and wrap in the carton; 3.5% in the full-trim-wrap in the bulkbin; and 7% in the full-trim-wrap in the carton.

The treatments not requiring wrapping took about half as long again as the controls to pack, while the treatments requiring wrapping took an average of three and a half times longer. These times can only be taken as a guide because of the combination of experimental and commercial conditions.

Experience from the trial indicated that a team of five is probably an optimum number for operations which include wrapping. Where a treatment does not need wrapping, perhaps four men would be sufficient. Four men is the normal number for a team of cauliflower cutters and loaders.

Finally, retailers who had purchased the wrapped cauliflowers were interviewed. All stated that they would buy cauliflowers which had been trimmed (to the level of the semi-trim) and which had been trimmed (full-trim or semi-trim) and wrapped, in preference to the fully leafed cauliflowers.

Conclusions

The results of these experiments have indicated that cauliflowers can be trimmed of a large number of their leaves and transported and marketed with even less damage than the present method of individual loading in full leaf. The substantial advantages of trimming the heads, at least to the level of semi-trim, are that the litter problem at the markets and at retail level is largely overcome and that transport costs per cauliflower are much reduced. All treatments gave a good outturn and the decision as to which treatment to use could be made by the grower in the light of his own farm set-up.

Trials are continuing to further examine economic aspects of these handling and packing methods.

Discussion

In untrimmed cauliflowers the bulk of the leaves can be as much as twice that of the curd.

Although the 1168 x 1168 mm (46 x 46 in) pallet is the Australian standard, and very widely used, the 1100 x 1100 mm I.S.O. pallet is likely to come in; it is the standard pallet in Japan and the U.S.A. is considering its adoption as it fits into an I.S.O. container (internal width 2300 mm).

PRE-PACKAGING OF BANANAS

W.J. Greenhalgh and R. Worrall*

Bananas are transported in the green state, ripened at the central markets and sold to the retailer when part coloured, (stage 4). It is at this stage that some merchants have pre-packaged to provide fruit prepared to the specification of the retailer. Fruit is therefore packaged twice, the first time in a bushel container traditionally suited to manual stacking; the second time in units required by the supermarket customer.

Pre-packaging at source would appear to offer several advantages. It would halve the number of times the fruit is packed; it would provide a protective covering for the fruit for more of its post-harvest life, and it would transfer a section of the labour input from urban source to rural source. This latter advantage would be in keeping with the community need to provide jobs in rural areas and would be in keeping with the desire by the producers to be more closely involved with the marketing of their crop.

Because pre-packaging increases the bulkiness of the produce, the traditional bushel case would have to be replaced by a bulk container. Some adjustments would need also to be made to either bring the ripening atmospheres to these containers or to get the bulk containers in and out of ripening rooms.

In any case it would have to be shown that the physiological processes of ripening could proceed normally with plantation pre-packaged fruit.

In January, 1972, Mr Ross Worrall, a final year student at Sydney University, began pilot studies at the Alstonville Tropical Fruit Research Station, using a range of film materials supplied by Borden Chemical Company (Australia) Pty. Limited. In all treatments the fruit was fully enveloped in the film, either as plastic bags (polyethylene films); over-wraps (self-clinging PVC), or over-wraps on flat bottomed polystyrene trays (heat-sealed PVC). Comparisons were made between samples packaged before and after routine gassing with ethylene.

All the bananas packaged in PVC following gassing, and those in polyethylene bags both before and following gassing, failed to ripen further.

However, with one of the cling films, fruit over-wrapped before gassing ripened normally, but more slowly, than unpackaged fruit. There was, however, considerable variability between packaged units, some units at colour stage 2 (green) with some at stage 7, (yellow, lightly flecked with brown).

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2006.

Since the films were very permeable to ethylene, the difference were thought to be due to internal atmospheres varying in O_2 and CO_2 concentration. The permeability of the most satisfactory film was given as 2,500-3,000 cc/24 hr/100 sq in./atm with respect to oxygen, and 16,500-18,250 cc/24 hr/100 sq in./atm with respect to carbon dioxide. This was a PVC film developed for pre-packaging of red meats.

This promising PVC film and perforated polyethylene bags were used in a trial consignment of some five cartons each of the pre-packs for comparison with similar quantities of unwrapped hands or clusters in conventional cartons. The fruit was consigned by rail to Sydney where it was treated in commercial ripening rooms. Wrapped fruit suffered almost no superficial skin injury in transit and was of excellent appearance when removed from the cartons. However pulp temperatures were elevated, especially in the polyethylene bags. Although the bags were perforated, the loose nature of the pack resulted in restricted air circulation where the bags had been tightly filled into cartons. Even with PVC over-wraps which allowed better air circulation between the packages, pulp temperatures rose to $23.5^{\circ}C$. At this temperature, and with internal oxygen levels varying from 5-15% and CO_2 levels from 3-10%, the fruit became green ripe. These results suggested that over-wrapped fruit would need to be transported at lower temperatures and be provided with more air circulation than conventional packs. The trials encouraged the belief that superficial injury to the skin could be minimized with plantation pre-packing.

In view of the difficulties with totally enclosed, (over-wrapped) packs, a further series of trials was carried out in September using band-wrapping. In these packs, clusters of green fruit from Avoca were wrapped with PVC film of 12 cm width so that the girth of the cluster was protected by film but the ends were open. Two kinds of cling film and two kinds of shrink film were used. The shrink film was applied loosely, heat sealed with an 'L' sealer and passed through a heat tunnel where monoaxial shrinkage provided a snug and compact package neatly fitting to the cluster along the edges of the film.

Wrapped fruit ripened at the same rate as the unwrapped fruit. The rate of progress through the skin colour stages 4 to 8, and the stage at which the upper level of sugar content was attained, was similar for all treatments. Scuffing and scratching of the skin was reduced in all band-wrapped fruit compared with the unwrapped clusters. At the end of their shelf life the various packs were assessed for appearance and attractiveness. A panel of 14 judges agreed that the clusters band-wrapped in cling-type film were more attractive than

unwrapped clusters. A vegetable-type film gave a slightly better pack than the red-meat-film found so successful in the earlier trials. Unwrapped clusters were limp and straggly and the skin of the fruit had developed a dry and scuffed surface texture. Shrink-wrapped clusters maintained their compact presentation and skin texture was good but the tension at the edge of the film had relaxed giving a loose and untidy appearance to the film. There was no evidence of injury to the fruit from its passage through the heat tunnel.

These preliminary trials have shown that band-wrapping at the plantation is quite feasible provided the industry is prepared to make the necessary developmental changes concerning the transport container and ripening techniques. Over-wrapping would require more detailed research before it could be seriously suggested.

The cooperation of the N.S.W. Department of Agriculture and the CSIRO is gratefully acknowledged. The project was suggested by B.R.A.C. and financed in part from a R.C.D.F. grant.

Discussion

This work is a useful preliminary study, also of value because of the involvement of a University student. This kind of activity could be developed to stimulate more student interest in the problems of marketing fruit and vegetables.

PACKAGE PERFORMANCE EVALUATIONS

D. Schoorl*

Introduction

There is no doubt an undue proportion of fruit is bruised at some stage between grower and consumer. Schoorl has unpublished data to show that the average percentage of bruised apples is 10-15% in tray packs, and 15-24% in pattern pack cases after a journey of 1,000 miles and six handling operations. Peggie (1968) reviewed problems associated with the retail marketing of fruit and vegetables, and the poor quality of fruit in retail shops was emphasized.

The fruit deterioration may result from natural processes (physiological), attack by decay organisms (pathological), or physical damage. The prevention of physical damage to fruit by better packaging and handling is of major interest in the packaging research program at Redlands Horticultural Research Station.

Physical Damage to Product

The most important function of the fruit package is the prevention of damage, which not only alters the appearance and quality directly, but also hastens ripening and rotting (Sommer *et al.* 1960). Packing, handling and transport of fresh fruit cartons subjects them to the following detrimental influences -

1. Load forces
2. Impact or drops
3. Vibration
4. Abrasion

1. LOAD FORCES

Load causes damage as a result of weight or pressure acting on the fruit. Nelson and Mohsenin (1968) have made a comparative study of static and impact bruise characteristics, which showed that the depth:diameter ratio of the bruise was, as expected, greater for impact bruises. Because of the time element, together with dead loads involved in load forces of bulk bins, etc., the mechanics of the force-deformation relationship is usually a creep phenomenon. The analysis of this problem from a rheological point of view has been

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Paper presented by J.R. Blake

discussed by Mohsenin (1970) and Wang and Chang (1970).

Load or compression bruising can occur because of -

- (i) Box failure - when a fibreboard box collapses or partially collapses, the fruit is required to carry the weight of boxes stacked above it.
- (ii) Packing or lidding pressure - pressure exerted on fruit during the packing operation, and pressure exerted in the process of securing the lid of the container.
- (iii) Static pressure of fruit - this is the weight of fruit forcing down on other fruit, e.g., in bulk bins.

Box Failure to Support Load Above

In the past there has been no trouble with collapsing wooden boxes under load. However, fibreboard boxes have become popular in recent years and many of these collapse if stacked too high, or in high humidity conditions. When box failure occurs the fruit must support the load, and bruising can occur if the weight is excessive or if applied for too long a time.

The load which a fibreboard box will support is not the same as its compression strength measured under standard conditions. Standard conditions for compression testing are $\frac{1}{2}$ " platen speed and $68 \pm 2^{\circ}\text{F}$ and $65 \pm 2\%$ R.H.) The load supported is affected by several factors:-

- (i) moisture content of the board
- (ii) length of time the load is applied
- (iii) the way the load is applied to the case, i.e., pallet profile and stacking pattern
- (iv) previous handling of package
- (v) factor for variability of containers
- (vi) support provided by fitting and contents

(i) Effect of Moisture in Fibreboard on Load Support Ability
Steenburg, Banks and Anderson (1963) have shown percentage moisture in fibreboard ranges from 10% at 68% R.H. to 20% at 92% R.H. Kellicutt (1960) and Stott (1959) have shown the loss of top to bottom compression strength of fibreboard boxes with increased moisture content of fibreboard. They found a 55% loss in compression strength from 10 to 20% increase in moisture content.

(ii) Length of Time Load is Applied to Box

Kellicutt and Landt (1951) have shown the ratio of static compression load to compression test load in percentage ($\frac{\text{load on box}}{\text{compress. strength}}$) and duration of load to cause box

failure. Their work showed that for 2 days survival time 70% of the compression strength can be supported. Stott (1959) showed at 10% moisture content the box can be loaded to 68% of its compression strength and survive 2 days. However at 20% moisture content the box can only be loaded to 50% of its box compression to survive without failure for 2 days.

(iii) The Way the Load is Applied to Case

In a single box top to bottom compression test, the box is compressed between flat steel platens. In actual practice fibreboard boxes are stacked on top of each other and boxes don't sit perfectly square. Kellicutt (1963) has shown the loss in compression strength from a single box to a perfectly aligned three high stack is 23%. If the boxes were stacked three high, but with the centre box deliberately placed $\frac{1}{2}$ in. out of alignment, the strength was reduced to 50%.

(iv) Previous Handling of Package

During transportation, stacks of corrugated containers are subjected to vibrations that can produce load forces much greater than static weights. These forces cause compression failure of lower containers in the stack, e.g., over the rear wheels of a semi-trailer. Godshall (1968) found failure of containers was due primarily to simple dynamic overloading or overloading resulting from resonant amplification of input vibration levels.

(v) Factor for Variability of Containers

All containers are not identical in compression strength so that a weak case from the batch placed at the bottom of a stack is likely to collapse. Schoorl (unpublished data 1971) found results indicate that a mean compression reading $\pm 10\%$ would account for most variation in compression tests.

(vi) Load Support of Fittings and Contents

It is well known that the cell pack apple cartons provide more support than the tray pack apple carton. The increased load support provided by duyfaylite apple packs is in doubt. No published work indicates exactly how much strength the cell fittings of a cell pack provide.

Mohsenin (1970) reports that fruit behaves visco-elastically and the elastic deformation is recovered when the load is removed. From observations in Queensland it has been concluded that Ellendale mandarins give very little load supportability to cartons in a stack. Ellendale mandarins are probably very plastic when deformed.

Prediction of safe loading limits for fittings and fruit in cartons has not been adequately reported.

Predicting Strength Requirement of Cartons

If the fruit is not going to help support the load, it is now possible to predict the strength requirements of cartons. Paine and Gordon (1971) report a safety factor between 1.5 and 5 is usually required, i.e., load multiplied by a factor of 1.5 - 5 equals compression strength required. Schoorl (unpublished data) has shown a safety factor of 3 is required at 10% moisture and 7.3 at 20% moisture. In cool stores operating at 90% R.H. it has been found cartons having less than 7.3 safety factor collapse if the contents don't help to support the load.

Balodis (1971) reports a satisfactory test schedule as follows:-

- Two weeks in a cool store with each pack under a 400 lb load.
- Two days in a conditioned room under a 300 lb load.
- Five days in a cool store under a 300 lb load
- One day in a conditioned room under a 200 lb load.

This test schedule is involved and time consuming, and the results only apply to the conditions of the test. It would seem more desirable to be able to design cartons to withstand all environmental hazards encountered as mentioned previously.

Depth of Fruit in Bulk Bins

The prediction of safe loading limits for fruit in bulk containers has been investigated by Nelson and Mohsenin (1968), Mohsenin (1970) and Lawton (unpublished data). Nelson & Mohsenin (1968) have shown the force acting on an apple in a bin. By determining the force to bruise with a static weight test, the maximum safe depth of fruit in a bin can be predicted. Lawton (1969) has shown bridging of fruit in a bulk bin occurs, which would take the weight off the bottom fruit. These bridges could however be destroyed by vibration in transit. Bridging of fruit in bins could explain why pockets of bruising occur in bulk containers.

The problem of predicting safe loading limits for fruit is to correlate flesh failure with maturity change, forces acting on the fruit, creep and contact area. It is important to know safe static load limits so that load bruising is not confused with impact or vibration damage. The problem solving would be quite different in each case.

2. IMPACT OR DROPS

A general review of commercial and laboratory testing for package evaluation is given by Schoorl (1968). A weakness apparent in many existing test procedures is their limited

scope; they tend to involve dropping a package a given height, a given number of times. Such procedures make it possible to assess whether or not a package will survive conditions roughly comparable with those of the test; but they do not normally provide information as to the extent of damage to be expected under conditions which diverge from the test.

The general bruise prevention performance of apple boxes dropped has been studied by Schoorl and Williams (1972). They found there is a critical height at approximately 2 ins. At or below this height the amount of damage is independent of the number of drops and is thus substantially random. Tests based on this or lower heights are therefore invalid. The remaining results can be fitted with the theoretically possible maximum accuracy by the expression -

$$\text{Ln} \left(\frac{y}{100-y} \right) = 2 - \frac{2}{kh + 0.2} + 1.0818 \text{ Ln } x$$

where x is the number of drops, h the height in inches, k is 0.05 for packed cases and 0.02 for tray cartons, and y is the percentage of fruit bruised.

Gordon (1963) has reported on the 'shock environment' that packages are likely to experience. They calculated from the number of handlings a package receives the probability of height and number of drops expected. By the use of drop probability data and package performance data of Schoorl and Williams (1972) it is now possible to estimate the extent of drop damage in transport from grower to consumer.

A review of drop height measurement has been given by Gordon (1963) and Schoorl (1971). The methods used for estimating drop height during handling include observation, films and shock measuring devices. In discussion with McDonald, Mechanical Engineering Department, Queensland University, it has been found back injuries to women have been considerably reduced since mini-skirts were introduced, whereas male back injuries have increased because of tight-fitting pants. The inability of male workers to bend properly could cause higher drops of packages.

The type of drop simulation machines available has been reported by Schoorl (1971) and Holt and Schoorl (1972). It is apparent some drop machines lack accuracy and the necessary range of drop height from 2 in. - 48 in. which is considered necessary.

3. VIBRATION

The effect of vibration injury to fruit has been studied by O'Brien and Gillou (1969); O'Brien and Fridley (1970); O'Brien *et al.* (1963, 1965, 1969 and 1970); Sommer *et al.* (1960)

and Gillou (1963). According to these investigators transport damage in fruits, referred to as roller 'bruising' is an important factor affecting the quality of fresh fruit. The cause of the damage is stated to be fatigue due to repeated forces of vibration on the fruit resulting in cell rupture beneath the skin. Since vibration damage is due to motion of the fruit in the pack, the magnitude of acceleration g was considered as the criterion for evaluating intensity of vibration. It was shown that the magnitude of acceleration in the upper layers of fruit where most of the damage occurred depended on -

- (1) the depth of fruit in the container,
- (2) the tightness of fill,
- (3) the type of suspension system used in the truck,
- (4) the magnitude of forced vibration from the road bed, and
- (5) the vibrating characteristics of the fruit species.

An excellent review of vibration in road vehicles is given by Stayner (1969) and Gordon and Wheeler (1965). The effect of road surface, speed of travel and vehicle suspensions is discussed. They report increased vehicle accelerations from rougher roads and higher speeds and that air suspension can make an economical improvement to the transportation environment. A good description of the mechanics of air suspension which improves the ride of road vehicles is given by Aldikacti *et al.* (1959).

Vibration Simulation

Gillou *et al.* (1962) reported that 30 minutes of vibration at 550 cycles per minute with a stroke of $\frac{1}{4}$ " gave good reproduction of transport damage. Jonson (pers. comm., Swedish Packaging Institute) said that they were using 360 cycles per minute and an amplitude to give 1.0 g . The Swedish research workers found poor correlation between this testing and commercial transport and were restudying vibration on packages and its simulation. Godshall (1968) showed that the frequency of input vibration is just as important as the g level of test. His work shows it is invalid to test at one vibration condition and conclude one package is better than another under actual transport conditions. The package and product must therefore be tested at the range of frequencies and g levels occurring in transport. Also the natural frequency should be determined to see if it is outside or close to the frequencies of the transport system. Schoorl (1971) lists the types of vibrators used at overseas packaging institutes.

The vibrator described by M.T.S. (1971) as supplied to the

author is the most useful. The hydraulic activated table has the wide frequency and acceleration level response required for simulating the transport vibration.

4. ABRASION

It is well known that banana skins mark readily when in contact with wood and fibreboard, but don't mark so readily when in contact with polythene. Similarly Freeman (1971) reports citrus suffer rind damage from abrasion with limbs and leaves. Balodis and Hawkins (1972) report on surface scruffing of cartons causing poor appearance of apple cartons.

Chen and Squire (1970) have evaluated the coefficient of friction and abrasive damage of oranges on various surfaces. They found the degree of abrasive damage on oranges depends largely on the roughness of the sliding surface, normal load, sliding distance and amount of oil and wax deposits on the sliding surface. The higher frictional force which occurs when an orange slides against another surface does not necessarily cause greater abrasive damage to the orange. This is because friction depends on adhesion and 'ploughing' and it is only the ploughing which causes the damage (see Mohsenin [1970] for discussion on friction).

The 'ploughing' is caused by the surface irregularities acting like chisels removing the cuticle wax layers of the fruit. It is necessary to measure the ploughing effect of surfaces in evaluating abrasive damage of surfaces in contact with fruit. This has not been reported in the literature as yet.

Conclusions

A general review of the main causes of fruit damage, viz. load, impact vibration and abrasion, is reported. It is apparent a much better understanding of these causes of damage has been obtained in recent years. The required fibreboard carton strength to resist load damage is now fairly well established. The use of package handling data with package protection will enable handling drop damage to be evaluated. The testing of packages under a wider range of frequency and accelerations will enable much better design of packages to withstand vibration damage. The measurement of the 'ploughing' damage caused by surfaces in contact with fruit will enable abrasion damage to be evaluated.

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FROM BITUMEN TO BLANKET - A REVIEW OF GAS-TIGHT COOL STORE PRACTICE

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Summary

The author has adopted the term 'blanket system' to apply to those cool stores in which refrigerated air is circulated around the outside of the gas-tight enclosure, forming a moving, cooling, blanket over the ceiling and around the walls, but not extending under the floor as in the 'jacket system'.

It is claimed, modifying the jacket system in this way removes one of the major objections to its use, namely, the high cost of hollow floor construction. The essentials necessary to successful controlled atmosphere (C.A.) operation are retained.

Developments here and overseas are traced, some inescapable conclusions point to further development of the blanket system.

Introduction

The history of the refrigerated C.A. storage construction has been one of continuing effort to produce an effective gas barrier (G.B.).

Volumes have been written extolling the virtues of a good G.B., but little about the practical ways and means of providing one. All agree that provision of a good G.B. is essential to the maintenance of a proper artificial atmosphere and all emphasize that the task is not an easy one.

In practice, the difficulties have proved to be very real, not eased by the need to utilize new and unfamiliar materials. An apparent absence of experienced people and/or a desire to go it alone, together with an incomplete understanding of the nature and duty of a G.B. have not in the past assisted in solving the problem.

This paper is mainly concerned with those aspects of cool store construction and refrigeration which have a relation to the functioning of the G.B.

Definitions

After visiting a considerable number of cool stores it became apparent that in a paper of this kind space should be devoted to an explanation of some of the features concerned.

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Overhead Coils

Bare cooling coils, usually 30 mm ($1\frac{1}{4}$ inch) nominal internal diameter arranged in banks suspended from the ceiling. Ammonia refrigerant may be pumped through the coils, i.e., 'liquid recirculation', or more usually expanded into the coils, i.e., 'direct expansion'.

Air circulation is induced by natural convection but in many instances fans have been installed to assist air circulation. The literature indicates that overhead coils are no longer used to any extent overseas.

Forced Draft Coolers (F.D.C.s)

A relatively small bank of closely spaced finned coils, with a powerful fan forcing air through them. Usually, the direct expansion system is used with ammonia or freon as the refrigerant.

There are instances in which the fan is placed in front of the coil to draw air through, such units are, in fact, 'Induced Draft Coolers (I.D.C.s)' and whilst slightly more efficient thermally, are not recommended, as the fan heat is added after the air has been cooled and this tends to lower the relative humidity (R.H.) in the store.

Insulation

In stores which do not operate on the blanket (or jacket) system the R.H. is determined by the temperature of the cooling coils. To enable a reasonably sized coil to operate at a high enough temperature and a resultant high R.H. it is necessary to provide adequate insulation. The blanket system removes this requirement and the cost of insulation may be directly related to the cost of refrigeration.

Temperature

Unless otherwise defined the temperature referred to is that of the fruit. It is common to find the temperature measured is that of the air near the door, less common to find fruit temperature measured and still less common to find fruit temperature within the stack measured.

Ventilation

The admission of fresh air to the sealed chamber to replace the oxygen (O_2) taken up by the fruit. A good indication that a chamber is gas-tight is the need to deliberately admit air.

Vapour Barrier (V.B.)

A membrane of bitumen, metal, plastic, etc., on the warm side of the insulation to prevent a massive ingress of moisture which may condense or freeze within the insulation.

Moisture logged insulation is only $1/10$ as good as dry insulation and ice bound insulation only $1/25$ as good.

Gas Barrier (G.B.)

Most V.B.s are inaccessible, are not 100% effective (for their prime purpose they do not have to be) and are therefore unacceptable as G.B.s.

The essentials of a good G.B. are:-

- Reasonably impermeable material.
- System of joins no less permeable than the parent material.
- Long term integrity.
- Ease of maintenance and repair in case of damage.
- Located so as not to form a vapour dam.

Gas-Tight

A room cannot be considered gas-tight unless it is necessary to admit fresh air to replace the O_2 used up, anything less than this constitutes a leaky room and makes the use of an atmosphere generator essential.

Testing

If a room passes a pressure test in which the time taken for pressure P to fall to $0.5P$ is 10 minutes or more, then the room is considered gas-tight.

Alternatively, if the room is charged with CO_2 and 5% or less of the charge is lost in 24 hours, the room is considered gas-tight.

Jacket System

The fruit in a sealed chamber surrounded by a narrow air space. Refrigerated air is passed over the ceiling, down all four walls and returned under the floor. The cooler is external to the chamber.

Blanket System

The fruit in a sealed chamber, the refrigerated air being passed over the ceiling and returned around all four walls. The cooler is external to the chamber. The floor is a normal cool room floor, probably un-insulated.

Primary Air

Refrigerated air from the cooler forced by the primary fan through the air space forming the blanket around the fruit. The primary air temperature will be about $2^{\circ}C$ ($4^{\circ}F$) cooler than the air within the chamber.

Secondary Air

The air or C.A. atmosphere within the sealed chamber which is circulated around the fruit by secondary fans located within the sealed chamber.

Early Developments

The work of Drs Kidd and West has been referred to on many occasions and it is pertinent here to point out that these pioneers did, in fact, point the way to the proper location of the G.B.

Fifty years ago a small experimental 'gas' store was constructed on the principle referred to now as the blanket system, but it appears that during the intervening years the significance of that early design was not fully appreciated. Of course in those days, the emphasis was on solving biological problems as indicated by the setting out of an 'Expedition to Australia' in 1923 to investigate 'Brown Heart'. Now with the development of the plastic tent we are back to square one.

It is also worthy of note that in the early days refrigerated storage for fruit was further advanced in America than in England, due no doubt to climatic differences, but the first commercial 'gas store for fruit' was constructed near Canterbury in Kent. The Ditton Laboratory was erected about the same time, 1930, in one of the most important fruit growing areas in U.K.

England led the way with C.A., development in most other countries has been post World War II.

Gas Barriers

Most people would agree without any hesitation that a sheet of metal would provide a good G.B., but for some reason it is not so easy to get a similar verdict for sheets of other materials. Possibly this is on account of undue concern about the inherent permeability of the material, whereas history shows that failures have been due to imperfections, faulty joins or damage rendering the G.B. discontinuous. Comment in the literature on this subject stresses the difficulty of providing a good G.B., the importance of the 'quality' of the installation and the necessity to use only well qualified and conscientious tradesmen.

The easy answer is to put the G.B. on the inside surface of the store because it is then fully accessible, but as it will form a vapour dam, troubles from moisture within the insulation can be expected.

Outer skins of sheet metal in pre-fabricated constructions offer a solution, provided the joins are sealed with a flexible material, a disadvantage is that the outer skin may not always remain accessible for maintenance. There are examples where the inner metal skin joins have been sealed as an insurance, but this cannot be regarded as a long-term solution.

The ideal place for the G.B. is the inner lining of a blanket store because the laws of nature operate to the advantage of the store building rather than to its destruction.

English Practice

In England initially, existing air stores were converted to C.A. operation by the addition of a G.B. consisting of a coating of petroleum jelly applied to the inside surface of the store, a messy procedure. Later, overlapping metal sheets were applied but the common method is the application direct to the insulation of a trowelled-on bituminous compound up to 6 mm ($\frac{1}{4}$ inch) thick.

On the Continent

In Italy and France linings of flexible materials glued directly to the insulated walls have been used as well as welded metal sheeting. Additionally, the French have developed silicone membranes with selective diffusion properties to control the atmosphere as well as working on the use of inflatable structures.

The Netherlands

In addition to the more usual application of lining materials the Dutch have been developing the use of 'partial jacket rooms' which may prove to be the same as blanket rooms.

Israel

The most common procedure is to construct a metal framed building with an all metal V.B./G.B. outside the insulation.

Canada

A lot of work has been done on the jacket system and whilst it is immediately applicable to C.A. the surface has only just been scratched.

America

It has been common practice to apply metal sheeting or foil in a manner similar to that adopted in England with the joints sealed with non-setting caulking compounds. Asphalt impregnated felt is used under floor insulation. Progress has also been made with the application of a sprayed on coat of polyurethane foam providing at once an insulation and an adequate G.B. provided the corners etc. are reinforced and the foam is very carefully applied. It can be readily repaired if damaged and has much to commend it, the principle drawback being a fairly high fire hazard if left exposed.

In the American context it must be realized that generators are extensively used which suggests that high standards of gas-tightness are not of great concern.

New Zealand

Some very useful work has been done with plastic tents but it seems that C.A. storage is not likely to be adopted on a commercial basis.

South Africa

Little interest is apparent in C.A. storage.

Australia

Most efforts to make existing stores gas-tight followed English practice, there was really no alternative. Membranes were applied to the inside surface, varying degrees of success were achieved but the use of generators proved to be essential.

Pre-fabricated panel construction has been used with success, further experience being needed to prove the long-term value of the constructions.

The blanket system is now reasonably well established in the form of plastic tents, refrigerated cooling coils, overhead or F.D.C.s being external to the tent. The secondary air inside the tent is circulated at a rate of approximately $13 \times 10^{-3} \text{ m}^3 \text{ s}^{-1} \text{ tonne}^{-1}$ (0.5 cfm/bushel).

Quote:

"It is difficult to understand why efficient air circulation has not become a general practice in all cold storage systems, large or small, for it is very evident from publications on the subject of refrigeration that the effect of efficient air circulation and methods of obtaining it were fully appreciated by early writers on the subject".

End of Quote.

The interesting point is that this comment was made in 1928 in South Australia.

Future Developments

The preservation of fruit has developed through jam making, bottling, canning, sun-drying, and cold storage to the latter combined with C.A.

Future developments in the cold storage of fruit will tend toward the blanket system whether in the form of a plastic tent or a more durable structure. Already growers are appreciating that apples remain higher in the bin after storage in a tent compared with a conventional cool store, i.e., weight losses are not so great. It is easy to maintain a high R.H. in a blanket store and, in addition, the G.B. is fully accessible for maintenance whilst the insulation is kept dry.

Information to be obtained from the blanket store now being evaluated at North Ryde should be of assistance and it would be pleasing to see Industry putting in some effort towards producing a cheap blanket store. A blanket store should economize on refrigeration capital costs and allow assessment of insulation on a purely economic basis in relation to refrigeration running costs.

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Discussion

Construction costs of blanket cool stores were reported to be 10 to 15% greater than conventional cool stores, but their refrigeration costs were lower. Few jacketed stores are in existence in Australia, all being associated with research facilities. There is little commercial interest in jacketed stores. Pressure release systems to compensate for barometric pressure changes are easy to make but cost is high and reliability doubtful. Major costs involved in C.A. stores are the provision of a gas barrier and a generator. The economies of scale involved where polyethylene tents are used as a gas

barrier in blanket systems are of the order of \$1.00 per bushel at 3,000 bushels capacity to 40 cents/bushel at 19,000 bushels capacity. Rigid stores offer similar economies but only at much larger capacities. F.D.C. was recommended over ceiling coils. Polyurethane foam sprayed onto cold room walls not only provided an efficient gas barrier but economic insulation as well. Application of polyurethane foam requires experience, otherwise uneven application can result. Its inflammability may provide some problems with regard to insurance premiums. Mr Atkins said that if he were a grower putting in a new C.A. store it would be a plastic tent 'blanket' store.

C.A. STORAGE OF FRUIT AND VEGETABLES

J.R. Blake*

Introduction

At the fifth Australian Fruit and Vegetable Storage Research Conference the question of controlled atmosphere storage and transport was reviewed by Hall (1968a).

The review traced the development of commercial controlled atmosphere storage from the original observations of Kidd and West to the developments which had taken place to that time. At that time, most work had been carried out to improve the storage life of apples and pears. This has resulted in recommendations for storage atmospheres which are generally suitable for the numerous varieties of apples and pears that are stored. The generally satisfactory nature of low carbon dioxide, low oxygen atmospheres for storage of most varieties had been confirmed in various countries.

Hall's review of the subject covered construction of stores and pointed out the necessity for air tightness and the means of achieving it. Problems associated with the conversion of normal atmosphere stores to controlled atmosphere stores, including the use of the polyethylene tent as a jacketed store, were also reviewed. Progress in the use of ancillary equipment, such as generators, scrubbers and control equipment and their future possibilities, were discussed. This paper will not consider these aspects as they will be dealt with separately by another reviewer.

In the review by Hall the effects of atmosphere on the development of decay were discussed but at that time little evidence had been produced to indicate the effect of atmospheres on rot development. Further developments will be reviewed here. Fruits other than apples and pears had not been extensively investigated and more can now be said in this field also.

The effect of rate of oxygen 'pull-down' is an aspect of interest and some further evidence has been produced as to its effect. The use of controlled atmosphere techniques for transport is also an area where progress has been made and the review will cover progress in this field.

Hall's review foresaw needs for further knowledge, especially with respect to the effects of time, temperature, carbon dioxide, oxygen and ethylene concentrations and perhaps also relative humidity. He indicated that "applied work should be concerned not only with effects on storage life, shelf life,

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and disorders but also on eating quality. In all studies the stage of maturation of the fruit must be taken fully into account, ---" He also indicated that because of the magnitude of the field, the approach should be limited to examination of the "--- respiratory responses and those responses, which can be judged visually or organoleptically, to low oxygen levels at various temperatures in high relative humidity keeping carbon dioxide at zero."

Unfortunately, at this point in time, this suggestion has not been taken up. Interest in the application of controlled atmosphere techniques seems to have been concentrated more on general effects and management of apple and pear stores and on fruits other than apples and pears as indicated by the fact that the two contributions submitted for review in this section are concerned with strawberries and lemons.

This, of course, is not to say that these are the only crops of interest in Australia with respect to controlled atmosphere. Some contribution has been made with respect to the use and design of generators and polyethylene tents as jacketed stores. Interest in the levels of ethylene in storage atmospheres is a new development and it is to be expected that now that a technique appears to be available for the destruction of ethylene in storage atmospheres (Scott, pers. comm.), further progress can be expected when this factor in the storage atmosphere is controlled. Further development of the polyethylene bag as a means of generating a controlled atmosphere during transport is taking place and this technique can be expected to find greater use as knowledge is increased.

Evidence of the widening interest in controlled atmospheres for the storage and transport of fruits and vegetables is given in the proceedings edited by Dewey *et al.* (1969). Unfortunately, I have not been able to obtain a full copy of these proceedings and have had to rely on a summary and short extracts published in Australian Air Conditioning and Heating.

Apples and Pears

Lutz and Hardenburg (1968) in a revised edition of U.S. Department of Agriculture Agricultural Handbook No. 66, give a simple statement of the general process of controlled atmosphere and modified atmosphere storage. They point out the benefit of temperature control and the effects of reducing oxygen and increasing carbon dioxide levels. The ways in which atmospheres may be generated and maintained are indicated and there are ample references to indicate the levels of gas concentration which have been found to be effective.

Controlled atmosphere storage is now firmly established as a means of prolonging the life of pome fruits and comprehensive

coverage of the subject as far as New South Wales is concerned is available in the papers presented to the extension school on Controlled Atmosphere Storage of Apples and Pears held at Orange, New South Wales, on 27th March, 1969.

In the past, a great deal of the literature that relates to the use of the controlled atmosphere effect for the storage of apples and pears has been produced by workers to confirm or modify previously reported effects of controlled atmospheres on particular varieties grown in their own environment (Smock 1966; Zanon 1966; Marcellin and Leteinturier 1966). At the present time, relatively few reports of this type are available (Padfield 1971a; Tugwell 1969).

There has been some research aimed at defining the requirements for successful storage. Hall (1972) points out that although scald is decreased by increasing the carbon dioxide content and by reducing the oxygen content of the atmosphere, controlled atmosphere storage or storage in sealed polyethylene bags commonly increases scald, this is because of restricted ventilation. Because of this, all apples and Packham and Anjou pears going into controlled atmosphere storage should be treated against scald. Tugwell (1969) reports similarly. Padfield (1971b) indicates that scald is reduced by the storage of Packham's Triumph pears in 1.5 mm polyethylene bags but after long storage scald becomes a problem. In this same reference Padfield indicates that brown heart may occur in polyethylene bags but that the risk is negligible if the bags are folded but unsealed. Brown heart development limited controlled atmosphere storage of both Winter Cole and Packham's Triumph (Padfield 1971a). The disorder caused more damage to early picked Winter Cole than to late picked fruit whereas late picked Packham's Triumph suffered more than those picked earlier.

Commission V of the International Institute of Refrigeration met in Avignon (France) in October 1968. Its proceedings are published in Annexe 1968-1 to the bulletin of the Institute. An inspection of the papers presented indicates that, generally speaking, the main areas of interest at that time lay in measurement of airtightness of rooms, the use and design of generators, and economics. This view is further confirmed by the subject matter covered in the Proceedings of the New York-New England Controlled Atmosphere Storage Seminar of 1966 where papers describing generators and the use of generators and lime scrubbers were predominant. The findings of Stoll (1968) indicating that stable conditions of temperature and relative humidity are to be recommended, are of interest. Investigations into variations in the components of the atmosphere have enabled the author to conclude that steady

rather than unsteady conditions give best results.

Hall (1968a) in his review indicated that claims had been made as to the benefits of rapid 'pull-down' using special external generators. Fidler (1971) reporting on the work of Cano and Sharples indicates that for the storage of Cox apples at 38°F under an atmosphere containing 2% oxygen, there was no difference of commercial significance, even if the storage atmosphere was developed within a few hours of harvest compared with the development of the atmosphere over a period of 20 days. Fruit ground colour became slightly more yellow and fruit texture was slightly more soft. This result confirmed observations made in the previous year. Despite this report a commercial controlled atmosphere store at Granite Belt in Queensland has been using liquid nitrogen to produce rapid 'pull down' of oxygen (Carroll, pers. comm.). The store operator is very happy with the process and will probably continue to use it. The use of nitrogen to obtain a quick 'pull down' continues to be promoted by commercial interests (Hart 1970).

It has been suggested (Eaves *et al.* 1968) that a preliminary exposure to nitrogen is beneficial to the subsequent controlled atmosphere storage of apples. Fidler and North (1971) have investigated the effects of an initial period of anaerobiosis on the outturn of Cox Orange Pippin apples and found that losses from rotting increased and that there may be a greater incidence of core flush and breakdown.

An investigation of the effects of simulated anaerobic conditions midway through the storage period indicated that an alcoholic taste may develop. These authors indicate that anaerobic conditions have been shown to occur in commercial situations, usually because of faulty measurement of gas concentration. Care should be exercised in the maintenance of oxygen measuring equipment to ensure that accuracy is maintained at low levels.

Gurevity and Pflug (1970) have investigated the effects of holding Jonathan apples of optimum maturity for controlled atmosphere storage, at elevated temperatures, prior to placing in store at 32°F with 5% carbon dioxide and 3% oxygen. The apples were held in normal and controlled atmospheres (3% carbon dioxide, 2% oxygen) for up to 4 weeks at temperatures ranging up to 74°F. The general quality (as measured by firmness and defects) of the apples receiving a controlled atmosphere pre-storage treatment, was always superior to the quality of the apples receiving a corresponding treatment in air..

Of interest in the storage of apples and pears are the results that are being produced concerning the effects of ethylene. Fidler (1960) has stated that provided apples and pears are stored correctly at low temperatures they are tolerant of quite

high ethylene concentrations because the fruit will not react at these temperatures. Since that time there has emerged evidence which indicates that ethylene can have effects on fruit stored at low temperatures. Forsyth *et al.* (1969) and Forsyth and Eaves (1970) indicate that removal of ethylene from the controlled atmosphere storage environment of McIntosh apples results in firmer fruit and a reduction in core browning. In a small trial from the Sandy Trout Food Preservation Research Laboratory in Queensland, Peacock (unpublished report) showed that Delicious apples stored in the presence of added ethylene (100 ppm) developed more bitter pit than similar fruit stored in the absence of ethylene. Ethylene had no apparent effect on the time at which superficial scald appeared, on the maximum amount of scald developed or on the time to reach this maximum. The work of Scott with respect to scrubbing of atmospheres to remove ethylene will be followed with interest.

From the information coming forward with respect to apples and pears it is obvious that controlled atmosphere storage is firmly established and any further improvements will be of a relatively minor nature based on local problems.

Bananas

The last 4 years have seen an increased interest in the application of controlled atmosphere techniques to other fruits and vegetables. At the 5th Investigators' Conference, the main reports involving other fruits and controlled atmosphere storage were those concerned with the use of sealed polyethylene bags for the transport of bananas (Tugwell 1968; Hall 1968a). Since that time there have been considerable developments using the sealed polyethylene bag. Bananas have been the subject of much of this investigation. Scott *et al.* (1970) compared sealed polyethylene bags with and without potassium permanganate and calcium hydroxide with unpackaged controls. They clearly demonstrated the benefits to be gained by the modified atmosphere that developed and further demonstrated the additional benefits to be gained when an ethylene absorbent was included within the sealed bag. About 2 weeks additional storage life was obtained by packing potassium permanganate with the fruit. This effect was further demonstrated when shipments of bananas in sealed polyethylene bags were made to both New Zealand and South Australia from growing areas in North Queensland and New South Wales (Scott *et al.* 1971). The fruit remained hard and green for periods of 8-18 days whereas fruit not packed in bags had ripened. The fruit was transported without refrigeration. Weight loss and mechanical injury were also reduced by the polyethylene bags. The value of polyethylene bags for bananas has been confirmed

overseas (Dewey *et al.* 1969). In this edited report Woodruff from the United Fruit Company reports on the use of controlled atmospheres generated in sealed polyethylene bags for the transport of bananas. The advantages of this type of storage are that heavier (more mature) fruit can be held for relatively long periods without ripening, rots and moulds are reduced, the fruit is maintained in a fresher appearance and a more flexible marketing of fruit on glutted markets is possible. Using refrigeration, fruit can be held for 30 days without ripening or rotting. In fact fruit can be held for 60 days without ripening but rots increase after 30 days. Liu (1970) has demonstrated that Purafil (alkaline potassium permanganate on a silicate carrier) can be used to absorb endogenous ethylene from pre-climacteric bananas in sealed polyethylene bags and so extend the storage life of the fruits. The possibilities of the method have been investigated in Taiwan (Chiang 1970) and Israel (Fuchs and Temkin-Gorodeiski 1971).

Strawberries

Berry fruits have long been known to be tolerant of high levels of carbon dioxide (Smith 1963). Certain fungal diseases are also controlled. Reports from the United States of America over a period of years have indicated attempts to use this effect for the transport of strawberries (Redit and Hamer 1959; Mitchell *et al.* 1964; Harris *et al.* 1967; Harvey *et al.* 1966; Harvey *et al.* 1968; Harvey *et al.* 1971). The work of Watkins (this Conf.) had its origin in these reports. Although still in a developmental stage the process is being adopted quite rapidly by growers and some problems are being experienced by transport operators in the physical handling of the quantities of fruit coming forward from growers. The possibilities of insulated sealed vehicles is being investigated. The problem of tainting mentioned by Watkins has been reported by Harris *et al.* (1967). It is thought not to be serious but further tests appear necessary. Fidler (1971) reports that berries stored at 45°F in air remained in excellent condition for 5 days but some rots developed after 16 days. Rotting was slightly reduced in 20% carbon dioxide but an off flavour was detectable immediately after removal from storage. This tended to disappear during a holding period at 65°F. It is interesting to note that after only 10 days storage at 32 and 33°F, in the presence of 20% carbon dioxide, berries developed a marked off-flavour and after 20 days, breakdown was extensive.

Citrus

The position of controlled atmosphere storage of citrus fruits has been reviewed recently by Seberry and Hall (1970). They

indicate the experimental work aimed at investigating controlled atmosphere storage of citrus fruits has produced rather variable results: "While some workers have claimed that C.A. storage of citrus has increased retention of flavour and reduced the incidence of rind pitting, others have reported increased level of fungal wastage and/or rind damage. It is also apparent from these reports that different species of citrus vary in their responses to C.A. storage and an atmosphere most suitable for one will not be so for another." There seems little point in repeating the review of Seberry and Hall here, but their final comments are of interest: "Research in Florida has indicated that C.A. storage shows more promise for extending the marketing season for Valencia oranges than other varieties of citrus. At present, in Australia, the evidence of possible benefits would not justify commercial trials.

"Further studies have been begun on the response of Australian citrus fruit to controlled atmospheres, particularly effects of volatiles on development of off-flavours. However, storage of oranges for longer than 4-6 weeks is likely to be profitable only in seasons when fresh fruit is either not available or of poor quality. For such short periods normal cool storage in air is quite satisfactory for fruit that has been correctly selected and prepared."

One aspect of atmosphere control which is relevant to citrus is that raised by Wild (this Conf.). There appear to have been few trials carried out with controlled atmosphere in citrus, where control of the ethylene level in the storage atmosphere has been attempted. Wild notes that new fungicides have permitted lemons to be stored for up to 6 months but the lemons degreen. The trials were designed to look at the means of preventing degreening. In the first instance tree storage was compared with cool storage, both treatments being examined with and without added gibberellic acid treatment. The results indicate that fruit sprayed with gibberellic acid for up to 6 weeks before harvest maintained a greened and fresher appearance in storage. Fruit which remained on the trees developed a more yellow colour than fruit that was stored. The second trial was designed to study the effects of controlled atmosphere ethylene free storage and the interacting effects of gibberellic acid and 2, 4-D in wax on the retention of green colour. The results indicate that controlled atmosphere ethylene free storage had the most pronounced effect on retention of green colour while presence of gibberellic acid caused additional retention. The trials are continuing. There are reports that a potential export market exists for lemons and that this market could be supplied if lemons could be stored in good condition for a

sufficiently long time. Gibberellic acid treatment and ethylene free controlled atmosphere storage could be the means of supplying this market and this work should be continued and expanded to other areas.

Other Fruit and Vegetables

There have been a few reports of avocados being subjected to controlled atmosphere conditions. Hatton and Reeder (1970) have investigated factors involved in the maintenance of quality in Florida grown avocados. They indicate that the Lula variety will store for about 1 month at 40°F in normal air storage. Under an atmosphere of 9% carbon dioxide and 1% oxygen the storage life was 60 days at 50°F. They indicate that tests are being continued to examine other closely associated atmospheres and temperatures and to compare the closed system previously used, with a constant flow system. A large scale test simulating commercial conditions is planned. Nel (1969) reports on storage trials with avocados in South Africa. The fruit were stored in layers of Cellophane film at 40°F for 3 weeks. Respiration data indicated that a controlled atmosphere effect was contributing to the result. Nel indicates that the Polar-stream technique using liquid nitrogen as the source of refrigeration was also tested. Storage at 40°F for 3 weeks with an oxygen content of 2% increased the remaining storage life compared with controls stored in normal air. No harmful effects were observed. Peacock (unpublished report) has investigated the use of the sealed polyethylene bag with potassium permanganate on a vermiculite cement block as a means of increasing the life of avocados at ambient temperatures. He compared the sealed polyethylene bag (0.015"), individually wrapped fruit (poly vinyl chloride 0.005") and normal air. The fruit was held at 20°C. After storage for 1 week a few control fruit had commenced to ripen; after storage for 2 weeks all control fruit were ripe and showing signs of dessication, fruit from all other treatments were hard and green although several showed symptoms of a rot developing. After 3 weeks storage, ripening had commenced in some of the fruit in each of the remaining treatments. The fruits from the treatments were then ripened. No quality differences could be detected. There was no difference detected between bagged and wrapped fruit. Because of problems that have been experienced in placing non-ripening fruits on distant markets some interest has been generated in this technique but rotting problems seem likely to prevent its adoption at this stage.

The papaw is another fruit which could benefit from controlled atmosphere storage. Akamine and Goo (1969) investigated

the effects of controlled atmosphere storage on papaws, particularly looking at differences in response between untreated fruit and others subjected to hot water treatment and ethylene dibromide treatment. The results indicate that atmospheres with 1% of oxygen do not increase the shelf life over that of normal air storage. However if the fruit was hot water treated (dipping at 120°F for 20 minutes) shelf life was increased in 1% oxygen and to a lesser extent in air. No benefit was obtained if the fruit was more than 50% ripe. The optimum ripeness range was from mature green to 10% yellow. The application of sealed polyethylene bag storage is being investigated at the Sandy Trout Food Preservation Research Laboratory. Watkins (pers. comm.) has arranged for Queensland growers to make consignments of papaws in sealed polyethylene bags containing potassium permanganate impregnated vermiculite blocks to an agent in Melbourne. Reports coming back from the market indicate that the agent is very pleased with the results. As the trial consignments have not been inspected by trained personnel it has not been possible to clearly establish the reasons for the improved outturn. Peacock (unpublished report) in two small experiments has investigated the effect of sealed polyethylene bags on the development of colour in papaws. The results obtained were somewhat inconclusive. In the first instance the polyethylene bag retarded colour development but was ineffective unless the fruit was green at commencement. In the second trial green fruit held for 2 weeks in bags ripened sooner than fruit out of bags. The final decision as to whether sealed polyethylene bags are beneficial for the transport of papaws will not be clear until further trials are carried out. Inconclusive results are probably due to the difficulty of ensuring that only preclimacteric fruit are used.

The proceedings edited by Dewey *et al.* (1969) contains a report by Hatton and Reeder of the United States Department of Agriculture from Miami, Florida, indicating that mangoes stored well in 5% carbon dioxide and 5% oxygen for at least 20 days, and were still palatable after 40 days. Full details of the maturity of fruit and conditions used have not been seen conclusions are difficult to draw. Workers at the Sandy Trout Food Preservation Research Laboratory have made an attempt to store unripe mangoes using the controlled atmosphere technique (Blake *et al.*, unpublished report). This trial sought to investigate whether green mangoes to be used for the manufacture of mango chutney could be stored so that the extremely short harvesting season could be spread to enable the more economic use of labour required to process the green fruit.

Unfortunately the trial had to be stopped after a short

period as mangoes which were apparently hard and not ripening commenced to soften almost immediately after harvest. It appeared that the ripening of the fruit was prevented while it was still attached to the tree but commenced as soon as the fruit was harvested. The report suggested that before the possibility of controlled atmosphere storage of this fruit was further investigated it should be preceded by a study to determine what relationship exists between fruit growth and its green-life. There is a continuing interest in the storage of mangoes to spread the relatively short season both from the point of view of fresh fruit and the processing of both green and ripe fruit. This work has not been proceeded with at this stage.

The possibility of storing tomatoes in 3% oxygen and carbon dioxide at zero, 3, and 5% have been investigated by Parsons *et al.* (1970). Tomato fruits, initially mature-green and held at 55°F for 6 weeks, kept significantly better in 3% oxygen and zero carbon dioxide than in air. Three or 5% carbon dioxide combined with the low oxygen atmosphere did not materially affect the amount of decay, and sometimes resulted in carbon dioxide injury. The storage of tomatoes by control of atmospheric pressure has been studied by Tolle (1969). The retardation of ripening was shown to be due more to the reduction of partial pressure of oxygen rather than a reduction of ethylene. Relative humidity needed to be controlled. Kasmire (1967) quotes results of trials made at the University of California, Davis, indicating that storage at 68°F for 8 days can result in large losses of fruit - 50% of the fruit held at zero carbon dioxide and 2.5% oxygen were unmarketable. He concludes that results of commercial and laboratory experiences with tomatoes stored under modified atmospheres suggest that users should proceed with caution when considering commercial experiments or storage. The storage of tomatoes whether it be by the use of normal storage techniques or by other means does not appear to warrant investigation in Australia as tomatoes are generally available throughout the year. Some problems of transport are experienced at certain times.

The use of controlled atmosphere storage for grapes is reported in the proceedings edited by Dewey *et al.* (1969). The process does not appear promising from a commercial standpoint. Controls in normal air storage, where sulphur dioxide was applied at weekly intervals, resulted in much better decay control than any combination of reduced oxygen and increased carbon dioxide levels. Increasing carbon dioxide levels to 15% did give disease control results comparable with sulphur dioxide but browning could make the treatment unsatisfactory.

Potato storage in controlled atmospheres has been investigated (Dewey *et al.* 1969). Loughheed, in these proceedings, reported the effects of controlled atmosphere storage on sprouting and quality of processed potatoes. Levels of oxygen and carbon dioxide up to 10% have a stimulating effect on sprouting but carbon dioxide levels of 15% or more inhibit sprouting completely. These are some indications that these high carbon dioxide levels cause some injury and it is concluded that it is not economically feasible to control potato sprouting by the use of controlled atmosphere storage. If potatoes are stored in controlled atmospheres they should be processed immediately after removal from storage since light coloured chips are produced. If held in air storage for some time after removal they will produce poorer quality chips. In the same proceedings (Dewey *et al.* 1969) Mattus reports that sweet potatoes stored satisfactorily at 6-7% oxygen and 3-5% carbon dioxide. Forsyth and Eaves (1968) investigated the possibility of storing potatoes under high levels of carbon dioxide to prevent greening. They determined that, provided potatoes were stored in an atmosphere containing at least 15% carbon dioxide, greening would not occur. They suggest that the demonstrated effect of carbon dioxide can be achieved by packaging potatoes in a sealed 4 mm polyethylene bag and keeping in the dark for 48 hours. After this time the bag will contain at least 15% carbon dioxide and subsequent exposure of the bag to light will not cause the undesirable greening. Taste tests carried out indicate that no off flavours develop.

Dewey *et al.* (1969) summarize the research that has been carried out to determine the tolerance and response of various species to controlled atmospheres, and indicate possible areas where the response can be used to practical advantage. From the summary it appears that considerable development is taking place to extend the life of many perishable products by the use of controlled atmospheres during transport. The response of cabbage to controlled atmosphere has been investigated by Isenberg and Sayles (1969). The best combination of gas mixtures ranged between 2.5 and 5% of both oxygen and carbon dioxide. In these atmospheres the cabbage retained their green colour and remained dormant longer. Very low oxygen and carbon dioxide gave a sweeter taste than normal, whereas high carbon dioxide gave a more pungent taste. Work by Suhonen (1969) indicated that damage to cabbage occurred if the carbon dioxide concentration rose to 15-20%. The report by Stewart *et al.* (1970) on lettuce indicates the type of trial that is being carried out to develop controlled atmosphere transport. Controlled atmospheres reduced the

incidence of pink rib but external appearance, butt discolouration, decay and tipburn were not influenced by transit atmospheres.

A slightly different use of the controlled atmosphere technique is reported by Uota (1969). As little as 125 p.p.m. of ethylene has been shown to cause 'sleepy' carnations but the effect is overcome by the presence of 7-20% carbon dioxide in the atmosphere. If 500 or 1000 p.p.b. of ethylene were present sleepiness was reduced by 30-40% carbon dioxide.

With the advent of liquid nitrogen as a refrigerant material, Hall (1968b) and Carroll (unpublished report) have reported the effects of 100% nitrogen applied for a limited period to a number of fruits and vegetables. Carroll treated various fruits and vegetables held at 38 and 54°F with 100% nitrogen for 1, 2, 3 and 4 days. He summarizes his findings thus:- apples - no transport problem envisaged; avocados - no serious problems likely unless the temperature is too low; bananas - transport under nitrogen is not advisable, particularly below 54°F (the results of Hall agree with this, except that with 99% nitrogen and 1% oxygen green fruit subsequently ripened satisfactorily); citrus - no problem envisaged; custard apples - probably not advisable; grapes - no problem envisaged at low temperatures; papaws - no problem, the method may be advantageous for ripe fruit; pears - no problem envisaged; beans - short post-storage life; cabbage - doubtful; carrots - no problem; cucumber - no problems but subject to chilling; peas - short post-storage life; tomatoes - delayed ripening. Hall's information is: lettuce - no problems; strawberry - no problem; spinach - a bitter flavour is produced; peaches - no problem in 1% oxygen.

Physiological Aspects

Over the last few years there has been considerable interest in the physiology and biochemistry of the origin and action of ethylene. A number of references have appeared which indicate the importance of ethylene in the controlled atmosphere situation. Fidler (1971) reports investigations into the effect of controlled atmospheres on the relationship between ethylene production and the climacteric. In a trial with Golden Delicious apples ethylene production commenced on the sixth day after storage at temperatures of 12 and 3.5°C, but was delayed for 44 days in an atmosphere of 5% carbon dioxide 3% oxygen. It was shown that cold storage dislocates the ripening processes that occur at 12°C, retarding some more than others. Controlled atmosphere storage exerts greater control over these processes, the control being greater in a 5/3 atmosphere than in a 0/2. Each storage atmosphere influences the ripening of apples so that from each are derived apples

with very different characteristics. Murata and Minamide (1970) showed that, for apples, retarded acid metabolism and inhibition of ethylene production are important factors in the maintenance of storage quality in controlled atmosphere stored fruit.

Quazi and Freebairn (1970) investigated the combined and separate influences of ethylene, oxygen and carbon dioxide on the ripening of bananas. High carbon dioxide and low oxygen concentrations inhibited ethylene synthesis and ripening in preclimacteric fruit and this is suggested as one of the ways in which controlled atmosphere storage conditions retards fruit ripening. Controlled atmosphere conditions were not able to preserve green fruit in which ripening had been initiated by treatment for 24 hours with 100 p.p.m. of ethylene. However, Hesselman and Fairbairn (1969) have shown that the rate of ripening of initiated bananas was found to be ethylene dependent in low oxygen concentrations. Fuchs and Temkin-Gorodeiski (1971), working with ripening and preclimacteric bananas sealed in polyethylene bags, conclude that, in the presence of high carbon dioxide and low oxygen concentrations, ethylene acts in different ways on the colouring and softening processes of these fruit.

Conclusions

There are many reports of the action of controlled atmosphere storage and its relationship to factors such as species, maturity and ethylene. Problems that occur and possible new approaches are being continuously applied at all levels of endeavour. The recent publications edited by Hulme (1970, 1971) contain many references indicating the specific areas in which progress is being made. Fruit is continuously changing both physically and chemically and it is perhaps not surprising that treatments applied should vary in their effect depending upon the time at which they are applied. However, workers should endeavour to specify the physiological state of their test material as accurately as possible so that the results of trial can be fully interpreted in the light of existing knowledge.

Recent published results indicate that the development of controlled atmosphere storage for apples is well established and most work is aimed at the physical and engineering aspects of storage. For other fruits and vegetables the process is being widely tried and it appears that there will be adoption of controlled atmospheres for the storage of certain products but that the main developments could be in the modification of atmospheres during transport, particularly in the use of sealed polyethylene bags. Control of ethylene appears to be an important aspect, particularly for tropical fruits. Basic

studies are beginning to unravel some of the more subtle relationships involved in the effectiveness of controlled atmosphere storage.

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Discussion

Advertising the qualities of CA stored fruit may have reacted adversely against normal cool stored fruit as far as the consumer is concerned. The tendency to hold CA stored fruit until near to the end of its storage life when quality begins to deteriorate is being overcome and CA fruit is being released much earlier in the season. Little work has been done on CA storage of stone fruits. Successful CA storage of apricots for 8 weeks was reported from South Australia. In this instance the product on removal was used for processing and no information was available on potential shelf life of the fresh product. Successful storage of Duchess (Williams) pears was reported from South Australia, approximately 10,000 bushels were stored successfully at 2-3% CO_2 and 3% O_2 and lime scrubbers were used to reduce CO_2 levels to 2-3% within 5 to 6 days. Outturn of the pears was excellent except for some incidence of hollow centre thought to be due to late picking, high field temperatures or slow cooling rates. CA storage had potential for export of certain tropical fruits, particularly bananas, avocados or mangoes. Export under CA would require polybags or containerization or specially modified ship's spaces. Polybag packaging would make fumigation difficult. It was noted that South African recommendations for CA storage of apples was 0% CO_2 and 2-3% O_2 whereas the Australian recommendations generally allowed 2-3% CO_2 with 2-3% O_2 .

C.A. GENERATOR DEVELOPMENT

P.J. Holligan*

Summary

The stages in the development of an open flame generator for production of a low oxygen flushing gas for controlled atmosphere storages is described. The safety features, performance and application to gastight rooms is discussed. The generator is in widespread use in New South Wales.

Introduction

The author in association with Mr K.J. Scott[†], commenced work in 1968 to develop a low cost controlled atmosphere storage system to enable smaller cool stores to be converted to C.A. storage. This work has resulted in the development of the plastic film room and open flame generator, and the application of lime scrubbers. This system enables small cool stores to be converted to C.A. storage with a per bushel total cost often lower than larger installations using more complex equipment. This paper describes the stages of the generator development and application of the unit.

Initial Development

Eaves and Lockhart (1964) described an open flame generator (Fig. 1), using natural aspiration of the burner and convection cooling of the hot exhaust gas in passing through a 50 foot length of steel pipe to the C.A. room.

To produce a generator for commercial use, it was considered that an easily regulated forced air supply was essential to maintain precise levels of oxygen in the exhaust gas. The use of a water spray for cooling would enable the generator to be compact and self contained. The fitting of adequate safety controls is essential for any LP gas operated burner system.

The first generator (Fig. 2), was manufactured using copper sheet for the burner tube and steel piping for the water cooler with a radial fan supplying air through a 1½" gate valve. An annular baffle below the burner concentrated air flow near the 2.6 lb/hr LP gas burner. Testing showed that the temperatures were excessive for the copper sheet above the burner. Flame out of the burner occurred before oxygen levels in the exhaust gas could be reduced to 2%. The apparent starving of the

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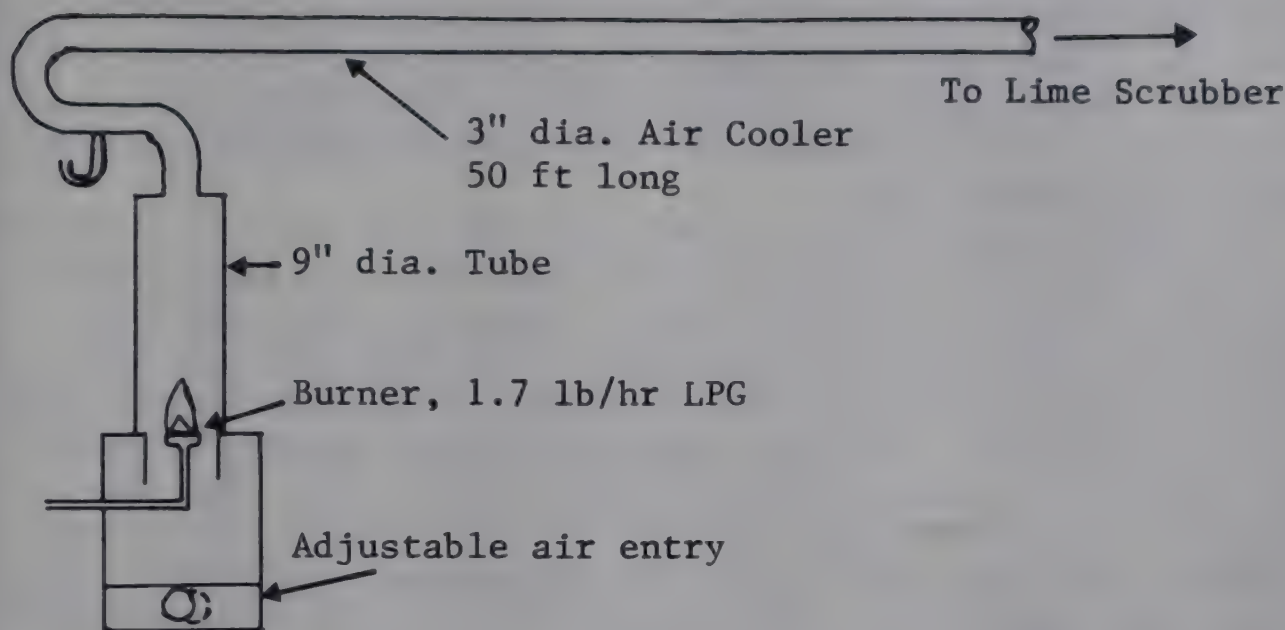


FIGURE 1. EAVES TYPE OPEN FLAME GENERATOR

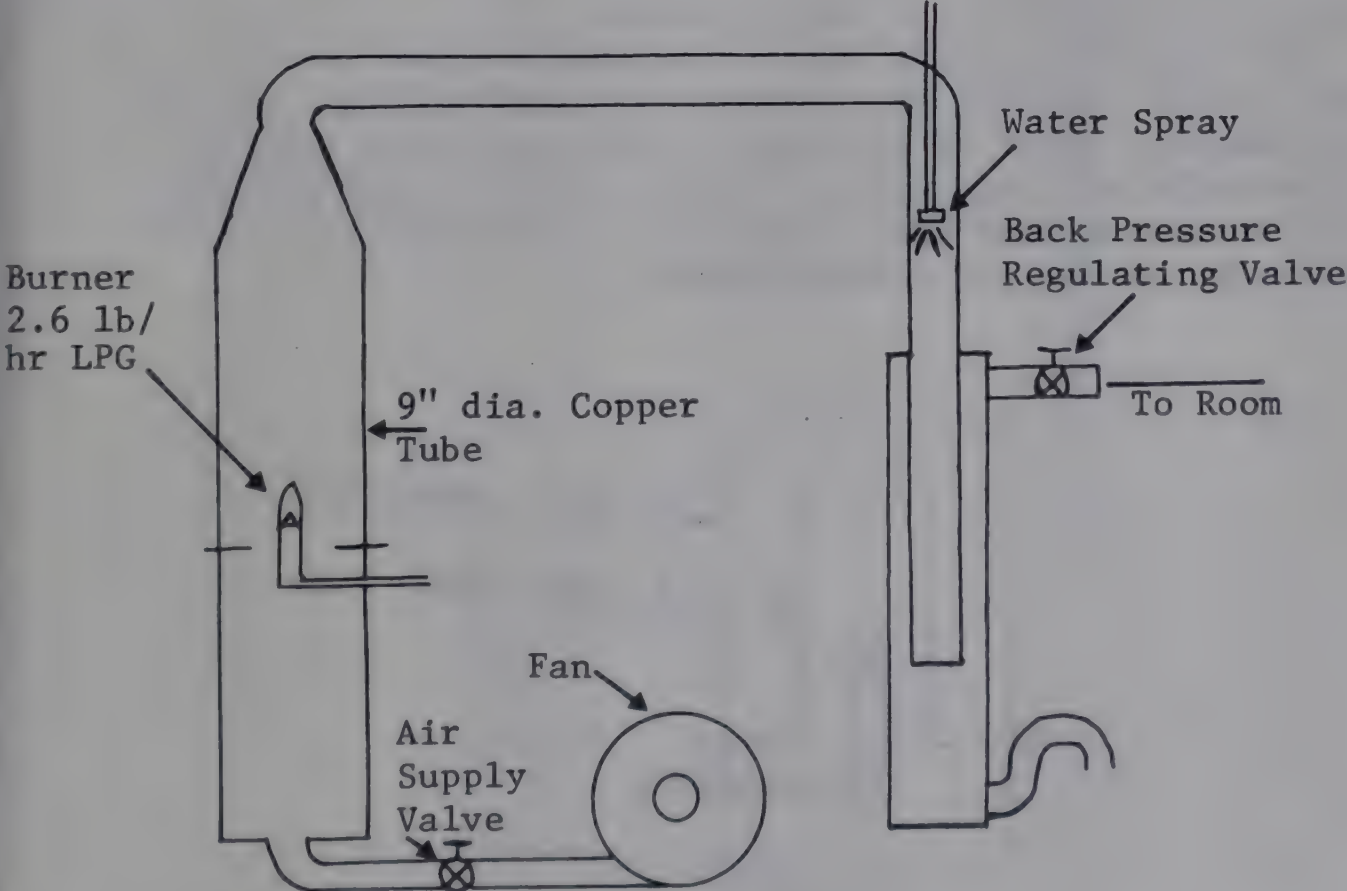


FIGURE 2. FIRST MODEL OPEN FLAME GENERATOR

flame for oxygen, and the simultaneous high level of oxygen in the exhaust gas led to the conclusion that the air was bypassing the flame zone. A piece of 4" downpipe was fitted over the burner to channel the air flow through the flame (Fig. 3). This had the effect of stabilizing the flame and allowing oxygen levels even below 2% in the exhaust gas. This generator was used for several room 'pulldowns' on the prototype plastic room.

The large copper burner column was replaced with 4" diameter 16 gauge Type 321 stainless steel tube with a flanged joint near the burner for burner access. Electric ignition was fitted and flame failure equipment. One high and one low pressure switch sensing from the burner zone ensured air flow in the generator. The high pressure switch ensured machine shut down if a valve on the delivery line to the room was closed. The low pressure switch ensured the air supply regulating valve was open before LP gas entered the burner. A timer was installed so that purging of the combustion chamber took place before the ignition spark came on.

The water cooler operated satisfactorily although it required fairly high water consumption. About 10 generators to this design (Mk I) were manufactured commercially for the 1970 storage season in New South Wales, and they have operated to the satisfaction of their owners.

The flame was stable down to exhaust oxygen levels of 0% but carbon monoxide was produced at this setting. At the recommended level of 2% oxygen, carbon monoxide was not detectable with palladium chloride, and the hydrocarbons in the exhaust gas were considered to be negligible after analysis on the gas chromatograph.

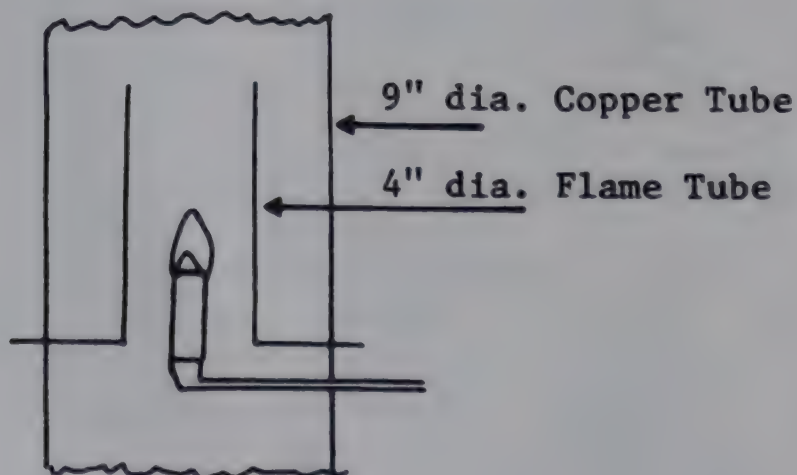


FIGURE 3. MODIFIED BURNER TUBE

Final Stages of Development

The principles incorporated in the Mk I unit were quite satisfactory, but it was considered that the unit could be simplified mechanically. The vertical orientation of both the flame and water spray caused unnecessary complication in manufacture, so the unit was redesigned into a single stainless steel tube (Fig. 4).

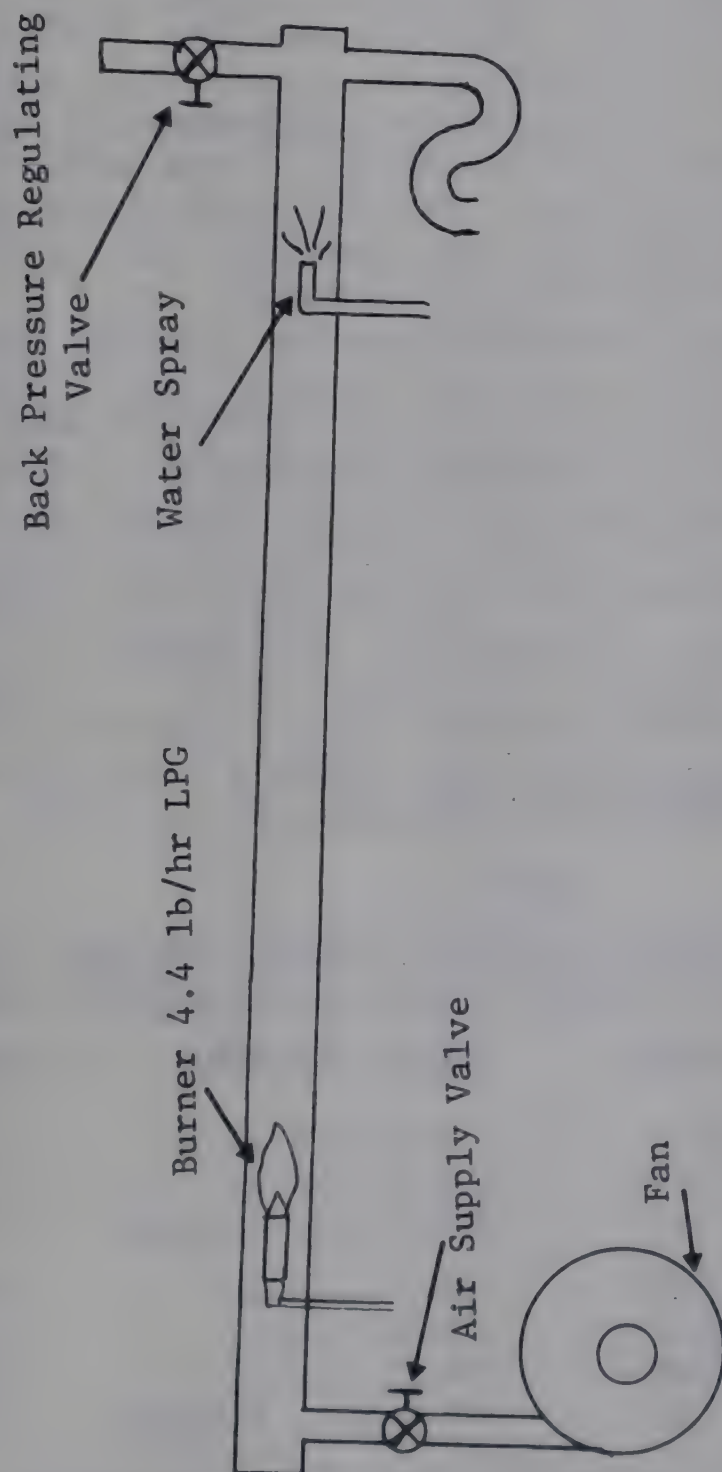


FIGURE 4. MK. II OPEN FLAME GENERATOR

The burner and thermocouple were assembled to a piece of stainless steel sheet rolled to form slightly less than a semicircle. This was fitted over a slot in the burner tube with an asbestos gasket seal, and held in place by pipe clips. The water spray was similarly attached. This method of construction allowed ready access to the water spray nozzle and burner for adjustment. A perforated sheet metal guard was fitted over the burner tube.

One commercial unit of this design experienced buckling of the burner tube due to differential expansion of the burner tube and the guard. This was overcome by slotting the guard fixing points and slotting the burner tube fixing. The cooling surface was also considered inadequate for operation with the larger burner (4.4 lb LPG/hr). Some water was entrained in the exhaust gas. The stainless steel tube exhibited signs of excessive temperatures. This was measured at 1600° F with the larger burner operating.

The final design has been developed to overcome these problems. The stainless steel tube has been replaced with 4" mild steel water pipe. This has been tested for 150 hr of operation, and the exterior scaling is considered negligible. Interior scaling appears to be avoided because of the low oxygen level inside the burner tube. In the event of ultimate tube deterioration, replacement of the heat affected zone would be a simple cutting and welding operation. The need for this however is considered unlikely for many years of operation. One or two nozzles are used in the water cooler depending on the available water pressure at the nozzles (Fig. 5). Table 1 sets out the nozzles, water pressure and flow rates.

TABLE 1
Cooling Spray Nozzles, Water Pressure and Flow Rates
for 54° C (130° F) Gas Outlet Temp. at 21° C (70° F) Ambient

<u>Burner size</u>	<u>Nozzles</u>	<u>Water pressure</u>	<u>Flow rate</u> G.P.M.
2942 (2.6 lb/hr)	1/A15	9-16 p.s.i.	2.0 min
	1/A20	16-18 p.s.i.	2.0 min
	1/A15	18 p.s.i. & higher	1.5 min
2943 (4.4 lb/hr)	2/A20	14-16 p.s.i.	3.5 min
	2/A15	16-24 p.s.i.	2.7 min
	1/A20	24-30 p.s.i.	2.6 min
	1/A15	30 p.s.i. & higher	2.0 min

The choice of two burners is available depending on the room size and desired rate of 'pulldown'. The smaller burner produces about 500 cu. ft/hr of flushing gas and the larger about 800 cu. ft/hr. Table 2 sets out estimated pulldown times for various rooms.

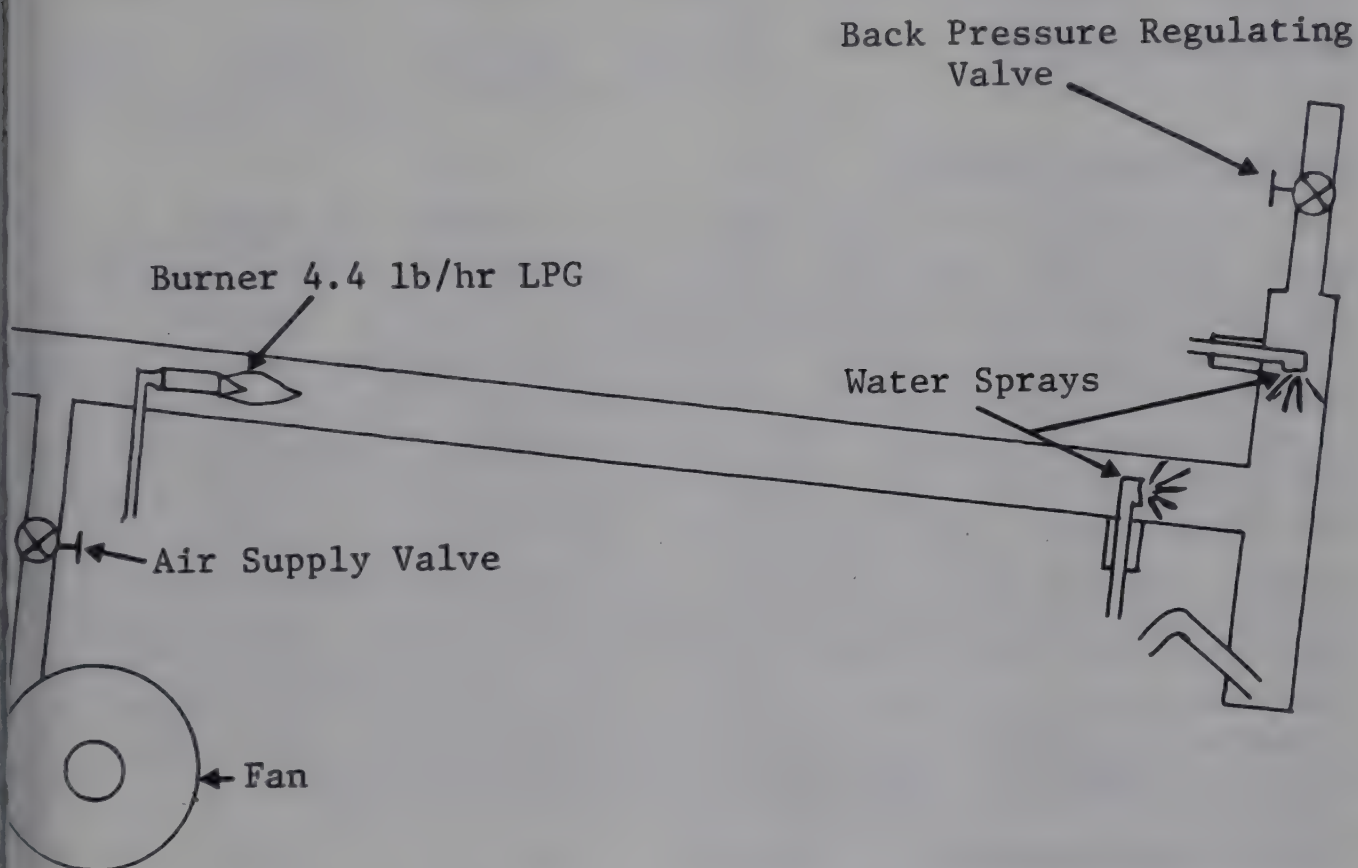


FIGURE 5. MK. III OPEN FLAME GENERATOR

TABLE 2

Estimated Pulldown Times for Room Full of Fruit

Burner Size	2.6 lb/hr		4.4 lb/hr	
Room size (bushels)	6,000	10,000	10,000	15,000
Pulldown 21%-6% O ₂	26 hr	43 hr	26 hr	39 hr
Pulldown 21%-3% O ₂	48 hr	80 hr	48 hr	72 hr

Carbon Dioxide Removal

The exhaust gas from the generator contains 2% oxygen and about 12% carbon dioxide. Eaves and Lockhart (1964) passed the generated gas through a scrubber containing trays of lime before entering the room. In our initial tests, two 44 gallon drums with three trays of lime in each were set up in series in this general manner. The drums acted as condensing surfaces for moisture in the gas and the drop in carbon dioxide level was quite small. This system was abandoned and the gas was passed directly into the room. The room scrubber was operated during generation, and this removed the excess carbon dioxide. Experience has shown that a 5,000 lb lime scrubber with fresh lime has adequate capacity for the 4.4 lb LPG/hr generator. A smaller scrubber may require intermittent generator operation to avoid excessive room levels of carbon dioxide.

Generator Application

The generator was developed specifically for use on plastic film C.A. rooms. One orchardist in New South Wales has two plastic rooms with a total capacity of 20,000 bushels operated with this generator. Another operator has 12,000 bushels in two rooms and will expand to 20,000 bushels next year. An orchardist with one 5,000 bushel plastic room is currently building a new store for 16,000 bushels in two plastic rooms. How should the operators on this scale choose between the open flame generator and a recirculating generator?

The basic considerations are cost and room gastightness. The recirculating generator is very efficient in maintaining a low oxygen level in a leaky room. The flushing generator (open flame is of this type) requires a high gas consumption on leaky rooms. Our experience with plastic rooms indicates that they are gastight rooms which require no generation after the initial 'pulldown'.

For a 15,000 bushel gastight room, Table 3 sets out a cost estimate for the two systems based on estimated LP gas requirements at \$0.10/lb.

TABLE 3

Cost Analysis for 15,000 Bushel Gastight Room

	Open flame generator	Recirculating generator 1 lb/hr
Capital cost (approx.)	\$1,000	\$2,700
Annual interest on capital 7%	70	189
Annual depreciation -		
over 5 years	200	540
over 10 years	100	270
Annual gas costs	186	85

For a gastight room, it is obvious that the open flame generator is more economical than the recirculating generator up to installed capacities well in excess of 15,000 bushels. The open flame generator with the large burner has an estimated shutdown time of 48 hours for a 10,000 bushel room compared to 4 hours for the 1 lb/hr recirculating generator.

For leaky rooms requiring once or twice weekly lowering of the oxygen level, the recirculating generator in general will be far more economical.

I believe that in addition to the cost of LP gas, C.A. operators are now realizing the considerable reduction in time and worry associated with running a gastight room in comparison with the frequent generations required for a leaky room.

Conclusion

The development of the low cost open flame generator has reached the stage where no further work is intended on the current unit. Experience and operator satisfaction over years of experimental and commercial usage has shown the unit to be both suitable for and acceptable to operators of gastight C.A. rooms. Fifteen generators are in commercial use in New South Wales.

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Discussion

Japanese experts are pleased with the performance of four Australian made open-flame generators which are being tested in Japan with plastic tent C.A. stores. The water cooling spray in the generator acts in addition as a gas-washing unit possibly removing SO_2 and soluble nitrates. Some work has been done to develop a CA open-flame generator using liquid heating fuel. It has the advantages of cheapness of the mass-produced home-heating unit and of the fuel, which now has a reduced sulphur content. Ethylene production by open-flame generators is very low, but information will be needed for LP gas and heating oil. A rainwater tank lowered over a concrete water trough has proved a satisfactory shell for a dry lime scrubber.

REMOVAL OF ETHYLENE FROM STORAGE ROOMS BY UV RADIATION

L.J.Scott*

During the past 8 years a method for considerably extending the storage life of bananas has been developed at Ryde (Scott 1971). This involves the treatment of the fruit with a suitable fungicide to control rotting by *Gleosporium musarum* and packing the bananas in a polyethylene bag. Before the bag is sealed an ethylene absorbent (potassium permanganate on an inert carrier) is placed on top of the fruit. While this technique appears to be suitable for packages of bananas in transit to market, it was thought that if a better method for removing ethylene was available it may be practicable to carry out short term storage at the packing plant. Such storage would be needed if export of bananas was attempted. The plastic controlled atmosphere room and open flame generator that was developed for apple storage (Holligan and Scott 1971) could then be used to provide ideal storage conditions for bananas.

Gane (1935) showed that ozone was capable of delaying the ripening of bananas. He found that the addition of ozone delayed ripening of the fruit but also injured it. A concentration that did not injure the bananas did not delay ripening. It has been generally concluded that the concentration of ozone required to delay ripening is too critical for commercial use.

More recently Spalding (1966) examined the use of ozone and he states that there appears to be little information in the literature that encourages the use of ozone for the commercial storage of fruits and vegetables.

Scott, Wills and Patterson (1971) examined the use of ozone by placing a small UV lamp GS411, made by General Electric, which produces traces of ozone, above 30 pounds of bananas in a 44 gal drum. The fruit was shielded from the rays by paper. It was repeatedly found that this lamp could remove the ethylene produced by the fruit and even after 2 months storage, injury did not occur to the fruit. Bananas produce trace amounts of ethane and propane and it was observed that the lamp removed these also from the atmosphere. The ability of the lamp to remove ethane suggested that something other than ozone was responsible for the lamp's effectiveness.

The predominant UV emission of the lamp is at 254 nm but it emits a trace of radiation at 185 nm. The 185 radiation produces ozone. Tests with other lamps showed that 185 radiation was needed to destroy ethylene. The 254 radiation of itself could not destroy

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ethylene, in fact, it often produced ethylene from plastic materials in the cabinet. Ethylene was also produced from a number of plastic films by exposing the films to sunlight.

It is well known that 254 radiation causes decomposition of ozone (Lea 1937) and it seemed that the simultaneous production and destruction of ozone may be making the system effective in removing ethylene without damaging the fruit.

Atomic oxygen is said to be produced when ozone is formed or decomposed by UV radiation and this is capable of breaking down a wide range of organic compounds.

Atomic oxygen is also produced by certain electrical discharges at 1 mm pressure. The need for low pressure severely restricts the uses of this system and it does not appear to have progressed beyond the curiosity stage.

In the method adopted by Scott, Wills and Patterson (1971), there is a considerable volume of the drum that is exposed to the radiation. It is presumed that the radiation, atomic oxygen and ozone are jointly responsible for the decomposition of ethylene.

The more usual method for exposing fruit to ozone has been to pump the atmosphere through a jacket containing the UV lamp or the silent electric discharge. In such a system the volume irradiated at any one time is very small. Under these circumstances, destruction of the ethylene would only be by the ozone that is pumped into the cabinet.

The next step was to obtain a more powerful UV lamp with similar characteristics to the small one. Such lamps do not appear to exist. So, it was decided to make the appropriate mixture of 185 and 254 radiation by the use of several different types of lamp. It was found that by increasing the 254 radiation the ozone level could be controlled without loss of effectiveness in destroying ethylene.

If a normal higher powered UV lamp that produces ozone is used the radiation will probably have an undesirable ratio of wavelengths 185 and 254 nm.

In a cabinet with this lamp the ozone concentration rises as the concentration of ethylene falls and the ozone soon reaches toxic levels.

It may be possible to overcome this problem by intermittent use of the lamp but this is hardly a practical solution to the problem.

A normal non ozone producing germicidal lamp does not emit at 185 nm and its radiation is predominantly at 254 nm. When ozone is exposed to the radiation from one or more of these lamps the ozone concentration rapidly falls. If both types of lamps are used together to irradiate an atmosphere containing ethylene, the ethylene is removed at a similar rate as with the ozone producing lamp alone, while the ozone level does not rise appreciably as the ethylene is removed.

The irradiation of higher olefines, such as butene, produces at first a number of lower molecular weight hydrocarbons which eventually disappear. It has been shown that the radiation converts ethylene to carbon dioxide.

As the system was effective in removing ethylene it was decided to examine the effect of the radiation on other nuisance gases. Carbon monoxide was easily removed, likewise dilute car exhaust gases and dilute coal gas. Ethane tends to accumulate at first but is eventually removed. The radiation is also effective in removing phenol vapour, contrary to expectations the ring structure was broken and butane and ethanol were detected very soon after irradiation began.

All these experiments were carried out with the lamps and gases in a single sealed reaction chamber. If we were scrubbing these gases from around biological material it would, of course, have to be protected from the radiation and atomic oxygen. Since atomic oxygen has a very short life and can be thought of as only existing in the path of the rays, any material likely to be damaged need only be shielded from the rays. It has been found that the most convenient system is to attach an external reaction chamber to the room from which the gases are to be removed.

Such a reaction chamber or scrubber has given good results over 6 months for removing ethylene from the atmosphere of 200 bushels of lemons. Current work aims at obtaining design information for scrubbers capable of handling larger amounts of ethylene.

It would appear that one could clean up contaminated air for experimental animals and plants that are housed in a partially closed system.

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Discussion

Recent development suggests that the ethylene scrubber can be scaled up to run a full size storage room with no more than 1 ppm O_3 in the storage atmosphere, which level seems not to be phytotoxic. Removal of ethylene (and other volatiles?) by $KMnO_4$ has possibilities for improving the storage of citrus fruits and the storage of pears, which show less brown-heart in the presence of $KMnO_4$. UV radiation may remove volatiles involved in the development of other disorders in ways at present not understood. Perhaps we should speak of controlled environment instead of 'controlled atmosphere', where control of ethylene and other volatiles, as well as CO_2 and O_2 , is carried out. The 'clean air' concept is becoming important in fruit storage.

TRANSPORT OF PRE-COOLED STRAWBERRIES UNDER HIGH CARBON DIOXIDE LEVELS GENERATED BY DRY ICE

J.B. Watkins*

Queensland produces approximately 600 tons of strawberries annually. The main producing districts lie within an area extending from 80 miles north to 30 miles south of Brisbane. The harvesting period commences in late May and may extend to early December. About one fifth of the crop is processed as jam or canned as whole berries. The major part of the crop, about two-thirds, is consigned by air interstate and to distant State markets. The main variety is Redlands Crimson, a variety bred by the Queensland D.P.I. Apart from the desirable agronomic features, Redlands Crimson is a highly coloured berry which is very firm when ripe.

Because the greater part of the crop is consigned by air, freight is a major cost in marketing strawberries. Although carriage by air is the ideal way of transporting highly perishable goods, air-freighted berries are sometimes handled carelessly at one or a number of transshipping points between the grower and the market agent. Queensland D.P.I. trials have shown that careful handling of packed berries is imperative for the marketing of high quality fruit. With road vehicles it is possible to transport berries at considerably less cost than air-freight and with less transshipping. The chief disadvantage of road transport is the increased time in transit and consequent loss of quality. Factors such as distribution of the load, truck suspension and truck speed are generally able to be controlled so that loss of quality due to road shocks is not a problem.

Following the early work by Kidd and West indicating the principles which have led to controlled atmosphere storage numerous workers have investigated the effects of carbon dioxide and oxygen applied to fruits. Early work on strawberries is summarized by Smith (1963). This review indicates that strawberries are tolerant of high concentrations of carbon dioxide and that certain fungal diseases are controlled. Attempts to use the effect of high carbon dioxide levels to maintain quality in strawberries during transport have been carried out in the United States of America (Redit and Hamer 1959; Mitchell *et al.* 1964; Harris *et al.* 1967; Harvey *et al.* 1966; Harvey *et al.* 1971).

The possibility of using road transport to obtain a better outturn of strawberries on the markets of Sydney, Melbourne and

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Adelaide has been investigated by the Sandy Trout Food Preservation Research Laboratory. Because of the greater time taken to get strawberries to market when road transport is used it was decided that precooling of fruit would be a necessary pre-consignment treatment. Because of the success in the U.S.A. of using a high carbon dioxide atmosphere generated inside a polyethylene bag, this method was investigated locally.

In these trials the berries, packed in punnets placed in fibreboard cartons holding either 12 or 20 punnets, were cooled overnight to a temperature of less than 45°F. A number of cartons were packed in a large polyethylene bag (0.0015 inch gauge) contained in a large outer fibreboard carton, and dry ice (2 lb of ice/100 lb of berries) was placed on the top carton prior to sealing the bag. A sheet of ½ inch thick foam insulant was placed between the dry ice and the top carton to protect the berries below from freezing. Berries packed in this way and consigned by road invariably arrived at the markets in excellent condition, the longest delay from harvest to market being 80 hours.

The initial trials were carried out using a carton made of double thickness corrugations but tests showed that the desired 20% carbon dioxide level was not reached. Subsequent trials used a carton sufficiently large to take 16, 20-punnet strawberry cartons and was lined with a large polyethylene bag. The carton was loaded from the top and the bag sealed by tying. The large carton contained approximately 240 lb of strawberries and 6 lb of dry ice was added before the inner polyethylene bag was sealed. Carbon dioxide levels were monitored and reached 57% after 40 hours. The container was then opened and the strawberries assessed for quality. Firmness and brightness were excellent, mould growth had been inhibited but a slight taint had developed when the berries were tasted immediately after opening. This taint appeared to fade with time.

Recently a special bulk carton (approximate dimensions - 37 inches long, 24 inches wide and 21 inches high) has been designed, to hold 10, 20-punnet cartons contained in a sealed polyethylene liner (0.0015 inch gauge). The bulk container includes an inner fibreboard sleeve. The sleeve protects the polyethylene liner, interfaced between the outer walls of the sleeve and the inner walls of the bulk container, from damage by the strawberry cartons. The container is an end loading carton which can be loaded from either end or both ends. The 10 cartons contained comprise two tiers of 5 cartons per tier with a fibreboard partition placed centrally between the two tiers. This partition adds stacking strength to the bulk container. Layflat tubing is used as a liner and

is made sufficiently long to allow each end to be sealed by tying after the dry ice has been added.

Road transport of precooled strawberries packed in sealed polyethylene liners with an atmosphere rich in carbon dioxide is being used by a progressive section of the industry. However the benefits of particular parts of the operation have not been clearly defined and the improvement in outturn may in fact be due to the use of precooling and the bulk carton which results in a minimum number of careful handlings rather than benefits from the added carbon dioxide.

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Discussion

High CO₂ has been reported to give good rot control in cherries and the technique used for strawberries may be of value in the transport of this fruit. The amount of dry ice

used would not materially contribute to cooling. Strawberries develop an alcoholic taint at 40-60% CO₂, but not at 20% which appears to be ample. Dry ice was being used in 1959 to provide high CO₂ concentration in an insulated box in which strawberries were railed from Scotland to London.

EFFECTS OF CONTROLLED ATMOSPHERE, ETHYLENE FREE STORAGE AND GIBBERELIC ACID ON COLOUR DEVELOPMENT IN STORED LEMONS

B.L. Wild*

Introduction

Trials to determine an effective long term storage method for main winter crop lemons were first initiated at the Gosford Citrus Wastage Research Laboratory in 1948. Recently developed fungicides coupled with previously established dipping techniques now make it possible to store lemons in a sound condition for periods up to 6 months. One disadvantage detracting from sale of this fruit is that it develops a bright yellow colour indicative of overmaturity. Research is now being concentrated on reducing this colour development during storage. Methods being tested include the application of gibberellic acid field sprays to trees, application of a post-harvest dip mixture of gibberellic acid in wax and controlled atmosphere (6 per cent O_2 - nil CO_2) (C.A.) ethylene free storage. Details of these trials are² outlined below.

Lemon Storage Trials - 1971 Season

Two long term lemon storage trials were conducted during the 1971 season. The first trial was designed to analyse the effect of gibberellic acid (GA) on green colour retention in lemons. This effect was studied in combination with different fungicide treatments and compared with fruit left on the tree.

Twenty trees on the Somersby section of the Narara Horticultural Research Station were used in this trial. Four treatments were applied and these were replicated five times. In early May, a 10 p.p.m. GA Spray was applied to two trees in each replicate while the other two trees received a control treatment of water spray containing 0.05 per cent wetting agent. Fruit from one of the sprayed and one of the control treatments for each replicate was picked on 18/6/71 and stored, i.e., 6 weeks after treatment. Fruit left on the remaining two trees in each of the replicates was picked some 9 weeks later on the 26/8/71.

The fruit from each tree in each replicate picked on the 18/6/71 was randomized into three groups and the following treatments applied:-

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1. Control, wax only.
2. Thiabendazole (TBZ) 1000 p.p.m. + wax.
3. Benomyl 500 p.p.m. + wax.

This fruit was stored at 13⁰ C and at 80-90 per cent relative humidity until 24/8/71. The number of fruit that could be assessed for colour development in each treatment group ranged from 72-111. Fruit remaining on the other two trees in each replicate was harvested on 26/8/71.

Fruit colour was assessed by one assessor using the following ratings:-

- 1 = Deep yellow
- 2 = Yellow
- 3 = Yellow + patch of green
- 4 = Green + patch of yellow
- 5 = Green
- 6 = Dark green.

A colour index for each treatment based on the above ratings was calculated by counting the number of fruit in each class, multiplying this number by the colour class number and totalling these values for each of the colour classes. This is summarized in the formula:-

$$\text{Colour Index} = \frac{\sum (\text{No. of fruit in each category} \times \text{category rating})}{\text{Total No. of fruit}}$$

Results

The results (Table 1) show that the GA treatment applied to the trees 6 weeks before harvest, resulted in a retention of green colour in the fruit, this fruit remaining slightly greener during storage (index 2.34 in fruit from the GA treated trees as compared with 2.01 in fruit from control trees). Gibberellic acid also appeared to retain the green colour in fruit left on the trees (1.79 in fruit from the GA treated trees as compared with 1.61 from control trees). The overall colour of fruit held on the tree from both the GA treated and control trees was more yellow than that of stored fruit.

From these results it can be concluded that fruit sprayed with GA 4 to 6 weeks before harvest maintained a greener and fresher appearance in storage. Fruit which remained on the trees developed a more yellow colour than that which was stored.

The second trial was designed to study the effects of controlled atmosphere (C.A.), ethylene free storage, and the interacting effects of gibberellic acid and 2,4-D in wax on the retention of green colour in lemons.

TABLE 1

Skin Colour in Main Crop Eureka Lemons 3½ Months
After Treatment with Gibberellic Acid Field Sprays

Treatments		Colour index					
Tree spray	Post-spray treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	MEAN
Nil	Fruit left on tree	1.45	1.54	1.65	1.68	1.72	1.61
GA	Fruit left on tree	1.90	1.42	1.85	1.85	1.93	1.79
MEAN							1.70
Nil	Control	2.09	2.02	1.80	1.92	2.21	2.01
Nil	Benlate 500 p.p.m.	1.97	1.92	2.09	1.95	2.09	2.00
Nil	TBZ 1000 p.p.m.	2.19	1.89	1.89	1.99	2.11	2.01
MEAN							2.01
GA	Control	2.21	2.46	2.32	2.33	2.11	2.28
GA	Benlate 500 p.p.m.	2.21	2.51	2.44	2.30	2.40	2.37
GA	TBZ 1000 p.p.m.	2.38	2.50	2.53	2.42	2.11	2.39
MEAN							2.34

(Fruit stored for 3½ months at 13° C and 80-90% relative humidity)

Eight cases of fruit were selectively clipped at the 'silver-green' stage of maturity from trees on three different growers' properties in early July 1971. This fruit was randomized into 16 half bushel units and the following treatments were applied:-

1. Plain air storage + wax containing 500 p.p.m. 2,4-D.
2. Plain air storage + wax containing 500 p.p.m. 2,4-D + 500 p.p.m. GA.
3. C.A., ethylene free storage + wax containing 500 p.p.m. 2,4-D
4. C.A., ethylene free storage + wax containing 500 p.p.m. 2,4-D + 500 p.p.m. GA.

Prior to treatment all fruit was washed and treated with 500 p.p.m. benomyl. The fruit was stored for up to 6 months at 13° C and 80-90 per cent relative humidity. During this time assessments of fruit colour were made on successive removals of half bushel units of fruit using the same ratings as in Trial 1.

Results

The results (Table 2) show that C.A. ethylene free storage had the most pronounced effect on retention of green colour. Colour index values for C.A. stored fruit were 2.29 and 2.46 (mean 2.37) as compared with index value of 1.73 and 1.93 (mean 1.83) for air stored fruit. Additionally, the incorporation of GA with 2,4-D in wax further increased the retention of green colour during storage. Index values for GA + 2,4-D wax treated fruit were 2.46 for C.A. and 1.93 for air storage (mean 2.19) as compared with a value of 2.29 and 1.73 (mean 2.01) for plain 2,4-D wax treated fruit.

Generally, the index values associated with the individual examinations decreased as the duration of storage increased, reflecting the obvious effect of length of storage on colour development.

Lemon Storage Trials - 1972 Season

Two lemon storage trials are being conducted during the current season. The first trial was designed to study the effects of GA tree sprays on colour development in stored main crop lemons when picked at four different stages of maturity.

This trial is still in progress; however, initial results obtained at the time of writing this report indicate that GA tree application consistently improves green colour retention in fruit on the tree and also fruit in storage.

The second trial, still being conducted was designed to study the combined effects of GA tree spray application and GA in citrus wax on colour development in lemons when stored under ethylene free atmosphere conditions for periods up to 6 months.

At present this trial is still in progress, and no critical examination of the fruit has been made.

TABLE 2

Effect of Post-Harvest Treatments on Skin Colour Development
in Main Crop Eureka Lemons Stored for 6 Months at 13°C and
80 - 90% Relative Humidity

*Examination No.	Green colour index (mean of 3 replications)					
	1	1A [†]	2	3	4	MEAN
<u>Treatment</u>						
Air storage - 2,4-D in wax	1.85	1.68	1.62	1.83	1.67	1.73
Air storage - 2,4-D + GA in wax	2.13	2.01	1.86	1.83	1.81	1.93
C.A., ethylene free storage - 2,4-D in wax	2.76	2.43	2.18	2.18	1.88	2.29
C.A., ethylene free storage - 2,4-D + GA in wax	2.83	2.55	2.34	2.58	2.02	2.46
Examination Means	2.39	2.17	2.00	2.10	1.85	

*Examination Date Nos:- 1 - 30/9/71, 1A[†] - 8/10/71, 2 - 16/11/71,
 3 - 17/11/71 and 4 - 13/12/71.

[†]Same fruit as in examination 1, stored for a further week at
 20°C, then reassessed for colour.

Discussion

Work in New South Wales has been on lemons from the Gosford area only but Victorian workers found similar effects from storage of Murray Valley lemons with alkaline permanganate and some of this fruit retained some green rind colour after 6 months. Internal quality is not a problem with this long stored fruit, the main disadvantage being the appearance of over-maturity. While GA has no direct effect on juice quality or yield, fruit size or skin thickness, it can hold lemons on the tree longer, resulting in larger fruit. However, at Gosford size is not a problem. The C.A. room remained free from odours despite high RH. Further work is needed to distinguish between

effects due to GA, C.A. and removal of ethylene. Until now, ethylene levels have been an uncontrolled variable in most storage trials. Handling of long-stored lemons in sizing, rewaxing, etc., results in excessive skin browning which is greatly reduced by GA and ethylene-free storage.

SOME RECENT STUDIES ON PHYSIOLOGICAL DISORDERS OF COOL STORED APPLES

J. Scott* and R.B.H. Wills**

At the 1964 and 1968 Conferences the effects of weight loss on low temperature breakdown were discussed in some detail. It was thought that the action of weight loss in reducing breakdown may be due to the loss of water or some toxic volatile substance being removed along with the water.

Since 1968 Wills and his co-workers have examined the effects of weight loss on the loss of volatile substances and it would appear that it is the removal of certain volatiles rather than the water that is the more important factor.

Wills (1968) stored fruit at three humidities. These treatments produced weight losses at the usual level for stored apples and losses above and below this level. He found that as weight loss increased the amounts of butyl, isoamyl and hexyl acetates given off by the fruit increased and the corresponding alcohols decreased. When the concentrations of these compounds were measured in the fruit high weight loss was associated with lower concentration of the acetate esters and of butanol.

When the volatiles given off by individual apples during storage were examined (Wills and Scott 1968) it was found that the ratios of ester to alcohol gave a good measure of the fruit's relative susceptibilities to breakdown later on.

The association between removal of acetate esters and reduced incidence of breakdown suggested that acetate was important, although there was no known role for acetic acid in apple fruit. It was found that fruit from treatments with higher incidence of breakdown contained larger amounts of acetic acid early in storage.

A number of workers have reported that breakdown can be considerably reduced by warming fruit during storage, if warming is done at the right time. Wills and McGlasson (1969) found that warming increased the loss of acetate esters and corresponding alcohols during subsequent storage at -1°C .

Studies of volatiles during storage from -1 to 10°C (Wills and McGlasson 1971) showed that fruits held at -1°C retained the greatest amount of acetic acid. At 0° and 2.5°C acetic acid content was also high but at 5° and 10°C it was very low. The loss of butyl, isopentyl and hexylacetates was highest at 10°C .

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and decreased markedly with decreasing temperature. It is suggested that low temperature breakdown does not occur at higher temperatures because of the reduced amount of acetic acid that is available to produce the disorder.

Acetic acid was the only volatile that was found to increase in the fruit with a decrease in storage temperature. Thus it appeared to fit the description of the toxic volatile substance that accumulated at low storage temperatures.

In studies of infectious diseases the usual approach is to isolate organisms associated with the disease, grow them in pure culture, reinfect the host with the supposed pathogen, then reproduction of the disease is the test of pathogenicity. A similar approach was used with chemicals. Substances associated with the disease were determined. They were then added to the fruit. If the disease was reproduced in the fruit then that substance was more likely to be involved in the production of the disease. Suspected compounds were added to the fruit by direct injection through the calyx into the core cavity, in 0.2 ml of water or ethanol. Control fruit, given either solvent were unaffected by this treatment. It was found that at concentrations which affected disorder symptoms (up to about 100 μ moles) damage at the injection site was rare. The compounds then move out into the cortex and affect the level of breakdown there (Wills, Scott and McGlasson 1970). There has always been a clear area of cortex that is unaffected by breakdown so the compounds have moved through the inner cortex without producing injury. Other work has shown that some compounds can move from the core through the flesh without affecting it but they influence a disorder occurring on the skin.

Acetic acid was the only one of the volatiles mentioned above that significantly effected breakdown. Substances suggested by other workers:- acetaldehyde, oxalacetate and sorbitol were also tested and found to be ineffective in reducing the disease. A quantitative relationship was established between the amount of acetate injected and incidence of the disorder for the two varieties of apple tested. Breakdown did not occur until at least 2 - 3 months after injection. This suggested that acetate needed to be metabolized further before the disease was induced. The substances known to be metabolized directly from acetate were then injected. Of those which increased breakdown mevalonate was found to be the most effective. This implicated isoprenoid metabolism (Wills and Scott 1971). Other isoprenoid compounds were compared. Geraniol was more effective in inducing breakdown and gibberellic acid considerably reduced it (Wills

and Patterson 1971). Subsequently abscisic acid was found to be even more effective in inducing the disease. Other growth regulating substances and inhibitors of isoprenoid metabolism were then studied. Most tended to increase breakdown. Some, such as Alar and CCC, had no effect.

The knowledge that GA, when injected into the fruit, could reduce breakdown, raised hopes of a control measure. GA was applied in various ways and better control was obtained with a dip than by injection. It was also effective applied in wax (Wills and Scott 1972).

Naturally occurring GA₃ was found to decrease in the control fruit during storage, as was the GA₃ injected into the treated fruit.

During 1972 we have further studied the application of GA₃ to breakdown susceptible Jonathans. While the above findings have been confirmed there have been some cases, particularly when the GA was applied late, when it was ineffective.

There has recently been a lot of interest in the effects of calcium on disorders. Calcium, other alkaline earth metals, and some other metals were injected into the fruit. Barium and strontium reduced the disease. It is not known whether these latter elements are simply replacing calcium, perhaps their effects are additive with calcium. Calcium and GA were combined with added effect. There are however considerable problems in getting calcium into fruit. This year we are trying to combine calcium and GA in a dip treatment. We are also looking at effects of minerals on other disorders. It is too soon to say we have a new practical control measure but these findings are encouraging.

Some Effects of Diphenylamine on Breakdown

There are few reports on the effects of diphenylamine on low temperature breakdown. Smock (1972 pers. comm.) has not observed any marked effect; Martin *et al.* (1970) reduced breakdown from 29.2% (CaCl₂ alone) to 18.7% by applying DPA as a preharvest spray (3,000 p.p.m.) in addition to the CaCl₂ programme. When applied as a postharvest dip DPA increased breakdown. In work at Ryde, DPA when injected (after harvest) into fruit with a low susceptibility to breakdown had no effect on breakdown. However when DPA was injected into fruit with a moderate susceptibility to breakdown it increased the disorder. Evidence was obtained that indicated DPA was moving from the core to the skin. It would appear that if breakdown was occurring soon after DPA was applied the DPA would be available in the flesh to influence the disorders. If however the disorder took a long time to develop most of the DPA would

have moved to the skin and would be unavailable to influence the disorder. In one case, in which DPA was injected into the core cavity typical DPA injury was actually induced on the skin after about 40 weeks storage.

While most of our recent work has been on volatiles and metabolites thought to be associated with breakdown we have some new information on weight loss. Under laboratory conditions we have consistently reduced breakdown, over a number of seasons, by increasing weight loss without shrivelling the fruit. It is more difficult to increase weight loss on a commercial scale and do it uniformly so that shrivelling is avoided. We have tried physical as well as chemical methods and the best methods have been a dip in 0.4 M potassium or sodium carbonate. The only difficulty with this treatment is some slight darkening of russeted fruit.

Packing anhydrous sodium carbonate with Jonathan apples in sealed polyethylene bags was very effective in increasing weight loss and reducing breakdown (breakdown in control 38%, in anhydrous sodium carbonate 12%). The anhydrous sodium carbonate was packed in a paper bag and it absorbed about 1.5-2 times its own weight of water without causing any difficulty and there were no shrivelled fruit. We would like to see this treatment tried at other centres.

We have examined the water contents of fruit which have had different levels of water loss and found that the water contents were the same. Apparently the water lost from the fruit by evaporation is regenerated within the fruit, presumably by chemical means.

A possible source is:- $\text{ACID} + \text{ALCOHOL} \rightleftharpoons \text{ESTER} + \text{H}_2\text{O}$, which would explain how acetic acid levels are reduced by high H_2O loss.

Core flush has been a serious problem in recent years in Jonathans, particularly in those from Victoria. The disorder was reviewed at the last conference by Carroll (1968). In 1971 Granny Smiths were severely affected in all eastern States. Warming, if applied at the right time, can reduce the disease (Padfield 1966; Carroll 1967) but this treatment is difficult to apply commercially. Martin and Cerny (1956) found that storage in zero carbon dioxide and low oxygen considerably reduced the disease in CA storage and this result was confirmed by Fidler and North (1961). We have obtained similar results but also observed increased yellowing and rotting in the zero carbon dioxide atmosphere.

During the past 3 years we have been working on the storage of Granny Smith apples at ambient temperatures of 45-50°F with a view to providing an inexpensive system for short term storage through the winter. The fruits' appearance was good after

months storage but by this time core flush was severe and this factor has prevented the commercial application of the method.

In 1971 when core flush was severe under commercial conditions we had the disease in ambient C.A. well before we saw it in other fruit in air, polybags, or C.A. In 1972 core flush developed later and at the time of writing no evidence was brought to our notice of core flush being a serious problem in commercial lines of Granny Smith apples in eastern Australia. It is suggested that core flush, as we have seen it recently is a disease associated with higher storage temperatures rather than with lower storage temperatures as it is with McIntosh in North America.

Forsyth and Eaves (1970) reduced core flush in McIntosh stored at 37°F in 5% carbon dioxide - 3% oxygen by absorbing ethylene with potassium permanganate. This treatment was ineffective on our type of core flush. Should some forms of core flush be controlled by removal of ethylene our UV scrubber could probably be developed to handle the ethylene produced by apples. Our other studies have indicated that core flush was reduced by increasing weight loss; this conflicts with Wilkinson's (1970) finding that high weight loss increased the disease.

Soft Scald

Recent studies have shown that hexanol is closely associated with the development of soft scald. Wills, Scott and McGlasson (1970) increased the disease by injecting hexanol and hexyl acetate into the fruit. Wills (1972) found that injections of hexanol and hexyl butyrate also induced the disease but a considerable number of related compounds had no effect. Wills (unpublished data) found that the level of hexanol in the tissues of Jonathan apples was a measure of the susceptibility of the fruit to develop soft scald. When hexanol was injected into fruit from different orchards the incidence of soft scald was related to the amount of hexanol that remained in the fruit.

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Discussion

While isoprenoid compounds affected breakdown in Jonathans, some increased and others reduced the disorder so that the metabolism of breakdown is still far from clear. Tree spraying with CA could be a worthwhile practical treatment to reduce breakdown in storage. It was suggested that diphenylamine might be a factor in the development of flesh browning in Jonathans and core flush in Granny Smiths stored in C.A.

FLESH BROWNING IN C.A. STORED JONATHANSC.R. Little^{*}

Flesh browning is a term which has come into prominence since the advent of controlled atmosphere (C.A.) storage on a commercial scale in Australia. Lesions are usually light brown to grey in colour, are well confined to the cortical tissue and have a dry texture and bitter taste. Affected fruit are firm, appear sound, feel turgid and give every indication of being quite acceptable. Diagnosis is only possible by cutting the fruit and for this reason is of no use on a commercial packing line. Carne (1948) described 11 types of breakdown. In all instances there was flesh discolouration, sometimes in the core tissue but mainly in the cortical zone. Some symptoms such as those occurring with water core breakdown are associated with radial patterns of glassy tissue extending outward from the vascular bundles. In most cases affected tissue is soft and dark and the disorders are usually associated with over maturity or large cell size which is often attributed to 'off' cropping or young fruit. In the following discussion although the term 'soft' or 'hard' flesh browning is sometimes used to describe a particular symptom, prior knowledge of storage or cultural factors is a necessary adjunct in differentiation by visual symptoms. The type of disorder which occurs predominately in C.A. stored Jonathans is well illustrated and described in the severe form by Hall (1971) in Figure 33L.

FIELD FACTORS KNOWN TO INFLUENCE FLESH BROWNINGMaturity

Early picked Jonathans have consistently failed to develop flesh browning (Little, Peggie and Taylor 1972). Traces of the disorder occurred in picks made very early in maturation, but a stage was reached where fruit susceptibility rapidly increased. This stage occurred where picking was delayed beyond mid-March and even the date considered by Tindale (1964) to be optimal for Victorian air stored Jonathans was too late for C.A. storage. Eaves *et al.* (1964) showed similar trends in maturity but concluded that other factors had a more profound effect on fruit susceptibility in C.A.

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Temperature of Storage

Dewey, Ballinger and Pflug (1958) found that temperatures near 0°C with CO_2 levels of 2.5% resulted in less loss than where temperatures were 2.2°C or 4.4°C . Trout, Tindale and Melin (1940) in work conducted over seven seasons showed that over six seasons a temperature of 0°C gave less wastage from breakdown (soft) in air storage than where higher temperatures were used. In later work Tindale (1966) stated that the level of wastage from breakdown (soft) in air stored Jonathans was higher when storage was at 0°C but the disorder occurred earlier during storage and with less total loss when the temperature was 1.1° or 2.2° . The disadvantage of the higher temperature is the loss of storage life. A combination of high initial temperature followed by storage at 0°C was considered to offer minimal wastage with maximum storage life. Padfield (1954) obtained similar results, but found no benefit in using step-wise cooling from 2.2° to 1.1° to 0°C .

Fertilizer and Fertilizer Uptake

There seems to be sufficient evidence to support the theory that much of the variability in response to storage treatments can be traced back to tree nutrition. Nutritional uptake, particularly of phosphate and calcium, is often difficult to achieve in sufficient quantity and this in itself may be affected by seasonal variability. Martin *et al* (1965) found that in seasons when breakdown was prevalent high fruit nitrogen could be correlated with high disorder incidence in air storage and high fruit phosphate could be correlated with low disorder incidence. Eaves *et al* (1964) reported that fruit harvested from orchards receiving high nitrogen fertilization were less susceptible to flesh browning in C.A. than fruit harvested from orchards receiving low nitrogen fertilization. In their work no fruit nitrogen analyses were made.

Other Field Factors

Martin (1953, 1954) found that within-tree variations, between-tree variations and between-season variations affected fruit keeping qualities. Dewey (1962) also commented that between-year variables caused greater variability in fruit susceptibility to flesh browning than differences in CO_2 concentration. A number of pre-harvest and pre-storage treatments investigated by Chace (1959) yielded inconsistent results in respect to the occurrence of the type of disorder we call flesh browning.

STORAGE FACTORS KNOWN TO INFLUENCE FLESH BROWNING

Carbon Dioxide and Oxygen in CA

The effect of carbon dioxide on Jonathan susceptibility to flesh browning was investigated by Little, Peggie and Taylor (1972). Three nominal CO_2 concentrations 0%, 3% and 6% were used at a standard nominal oxygen concentration of 2.5%. These trials showed a consistent increase in 'hard' flesh browning with increasing CO_2 . Fruit from the same source picked on the same days were air² stored in cabinets with sufficient ventilation to prevent a rise in CO_2 while maintaining a high relative humidity. Wastage from 'soft' flesh browning under these conditions was nearly twice as great as the wastage occurring in C.A. The 'hard' flesh browning in C.A., particularly where CO_2 exceeded 3%, never occurred in regular air storage. Where differentiation on texture or firmness was omitted total wastage from flesh browning was greatest in air storage, least in C.A. at 0% (nominal) CO_2 and increased with increasing CO_2 to 6%. These data support those published by Dewey (1962) which showed that the type of flesh browning occurring in C.A. stored Jonathans was aggravated by increasing CO_2 but total wastage from all forms of flesh discolouration was highest in air storage, and least where CO_2 was under 1%. Fidler and North (1961) obtained similar results with Cox's Orange Pippin, concluding that injury was CO_2 induced where C.A. was used and recommended storage without CO_2 .

Roberts, Wills and Scott (1965) classified all flesh browning lesions as breakdown and showed that the incidence of the disorder increased hyperbolically as oxygen decreased and decreased linearly as CO_2 decreased. A C.A. atmosphere of CO_2 1% and O_2 2.5% would therefore provide good control of flesh² browning and this supports data by Dewey (1962) and Porritt (1966), but Martin and Cerney (1956) concluded that 0% CO_2 was consistently superior to atmospheres containing CO_2 and their findings are more in line with Victorian work.

Weight Loss in Store

Scott and Roberts (1967) found a correlation between low weight loss and breakdown and their results help to explain the success of slow cooling at 2.2°C to the end of April, 1.1°C to the end of May and 0°C thereafter shown by Tindale (1964) to reduce susceptibility to flesh browning. The success in this technique of cooling may be due partly to increased weight loss at the higher temperature. However, Little, Peggie and Taylor (1972) found weight loss in C.A. to be half that in air storage but the total loss from flesh browning (soft and hard) was $2\frac{1}{2}$ times as great in air storage.

Other Field Factors

Observations made in Victoria, based on information from 10 orchards, indicate that mis-shapen Jonathans were more prone to flesh browning. Tree surveys have shown that such fruit are more prevalent on spurs or in the centre of the tree, and other cursory investigations have correlated mis-shapen fruit with poor seed formation.

Other Storage Factors

In 1970 fruit from the same orchard harvested on the same day was held in stores run by six well-known C.A. operators. There were three tent stores and three conventional gas proofed stores. Each of the store types used different methods of CO₂ generation. Weight loss and flesh browning were carefully assessed, and results showed a clear correlation between high weight loss and flesh browning. In other work it was found that weight loss, occurring early in the storage period, was more likely to increase susceptibility than weight loss occurring later in storage.

CONCLUSION

Work carried out overseas and in Australia shows that the overall level of wastage from flesh browning occurring in C.A. is lower than that occurring in regular storage. The type of flesh browning which is common in C.A. is difficult to detect unless destructive methods of assessment are used. In air storage flesh browning is characterized by soft flesh and in severe forms, skin darkening is visible. Work by Wills and McGlasson (1969) showed the involvement of acetate loss in reducing the development of breakdown in air stored Jonathans. It is not yet known whether similar treatments used with C.A. stored Jonathans would control the development of the type of flesh browning so common where this method of storage is used. However, the proposition that 'soft' and 'hard' flesh browning are caused by similar metabolic processes during storage is difficult to reconcile with different responses which are evident where one form decreases and the other increases as weight loss increases.

Applied research has shown that high CO₂ is responsible for the disorder in C.A. Apart from flesh firmness the injuries are so similar in air and C.A. that differentiation cannot satisfactorily be made until the role of CO₂ on fruit metabolism in C.A. storage is more fully understood.

Maturity is a factor which has more influence on fruit susceptibility than most other factors, but for total control fruit would need to be harvested at a stage before sufficient quality characteristics had developed.

Seasonal variability is regarded by some workers as a major factor in the predisposition of fruit to susceptibility yet little is known of the seasonal components responsible. Interpretation of research data where maturity is studied as a factor is restricted by lack of a practical objective measure of maturation. Similarly, limitations may be considered to apply where seasonal differences affect responses to flesh browning as the possibility of predicting these differences soon enough to allow for adjustments would be difficult.

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Discussion

The work has been done only with Jonathans from southern Victoria where the recommendation for selecting Jonathans for C.A. storage would be to pick early, before March 10, but the fruit must have sufficient colour to meet 'fancy' grade requirements but not be highly blushed, have a GGY ground colour and be evenly shaped. However, fruit picked so early would not have a good flavour.

A lenticel spotting has developed in low CO₂ as a faint pin-prick spot occurring at the lenticel, quite different from the much larger Jonathan spot. Above 3% CO₂ lenticel spot did not occur and even at the very worst covered no more than 5% of the apple skin.

The occurrence of lenticel spot increased in stores with a high relative humidity. It is apparent that certain Jonathan apples should not be C.A. stored, particularly if one or more of the pre-requirements just mentioned are not observed. At present there is a trend to open C.A. stores earlier each year and so unfortunately compete with air-stored fruit.

THE RELATION OF CHEMICAL ELEMENTS TO APPLE STORAGE DISORDERS

. Martin*

Calcium

There is now overwhelming evidence that low calcium status is associated with the incidence of bitter pit. There is considerable evidence that calcium is also involved with breakdown of the low temperature type but less evidence exists for a relationship with the senescent type.

Responses of Jonathan spot to post-harvest calcium treatments are less likely to be related to calcium status for there has been little evidence that preharvest calcium sprays have been effective.

The relationship of scald to calcium is only just beginning to be investigated. In Cleopatra, scald-affected fruit has a significantly higher level of calcium than sound and there was a significant positive correlation between scald incidence and calcium content even after elimination of N,P,K, Mg and mean fruit weight by partial correlation analysis. However responses to pre- and post-harvest calcium treatments have been inconclusive.

Prior to the development of A.A. analysis it was difficult to develop a close negative relationship between the incidence of bitter pit and the level of calcium or an increase in calcium content following pre- or post-harvest treatment. Since then we have had 10 years experience of a very consistent relationship which holds, usually at the $P < 0.01$ level, even when the other factors N,P,K, Mg and fruit size (mean fruit weight per tree) are held constant by partial correlation analysis. No other factor, except mean fruit weight, retains a consistently significant relationship with pit with this statistical treatment.

Many of the examples in literature where a calcium/bitter pit relation has not been shown may be due to failure to take account of the fruit size factor.

This calcium/pit relationship being so strong and the level of content embracing the range from highly susceptible to immune of 200-300 p.p.m. dry matter being almost in the minor element class, make the difficulty of correcting it somewhat surprising.

Experiments with pot and field culture have shown that there

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is little response in fruit to greatly increased calcium levels in the rooting medium. Pre- or post-harvest treatments, though useful, are never completely effective. Low calcium status and high susceptibility to bitter pit in the fruit can occur with high levels of calcium in the medium, calcium going preferentially to the vegetative growth, particularly under growth conditions occurring in young trees and light crops.

Attempts to reduce vegetative growth and hence competition for calcium by summer pruning, or growth suppressants such as DNOC, Alar and CCC, have shown some effect, but usually the improvement is small and could be due to the accompanying reduction in mean fruit size.

Attempts to find synergistic growth-active materials have been no more successful with preharvest treatment. 2,4,D, NAA, simazine, phloridzin, IAA and compounds of the adenine group have been tried. A small improvement has been achieved by adding DMSO on the supposition that this would assist penetration into the fruit but this was not economic.

Increasing concentration of tree sprays has risks of skin damage particularly with sensitive varieties such as Golden Delicious.

Post-harvest treatments have recently received more attention. It has been found that some varieties can tolerate quite high concentrations in the dip but some show calyx damage with levels of CaCl_2 above 5%. It is desirable to use the chloride as traces of nitrate have been detected following the use of calcium nitrate.

Many additives have been tried to improve performance but the only ones showing promise are DPA, NAA and GA. The combination of calcium salts and DPA is covered by patents. DPA usually (but not invariably) acts synergistically with calcium salts to reduce pit. On rare occasions it has been known to increase it.

Post-harvest treatments with calcium salts usually reduce breakdown incidence but the addition of DPA has a variable result.

Experience with GA is limited and more trials are necessary before any firm announcement can be made.

Nitrogen

Bitter pit affected fruit has a higher protein N than sound fruit of the same size from the same tree, but the levels of total nitrogen may not be significantly different. It is obvious that any effect of high nitrogen level must operate through its effect on other factors. The higher levels of protein nitrogen are related to the higher respiration rates at harvest shown by pit susceptible fruit.

Between trees, the relationship between bitter pit and nitrogen is always positive and is sometimes significant even when all other factors (including calcium) are held constant. A similar situation exists with protein nitrogen. The relationship is probably more consistent under very low calcium levels.

High nitrogen nutrition by ammonium salts depresses calcium levels in fruit and pit level responds, and it seems probable that the effect of nitrogen on pit operates mainly through the calcium mechanism; when nitrogen (particularly protein nitrogen) has an effect independent of calcium it is operating through an increase in respiration rate.

The relationship of nitrogen and breakdown is much more uncertain. Very low nitrogen, by increasing maturation rate, may increase susceptibility to senescent breakdown. For low temperature breakdown, comparisons of sound and affected fruit do not show consistent differences in nitrogen levels. Between trees the significance of simple correlations does not survive partial correlation analysis. This suggests that if nitrogen has a role, it operates through other elements and calcium seems the most likely. High calcium treatment often reduces protein nitrogen level and respiration rate and this is a possible mechanism for the effectiveness of calcium in breakdown reduction.

No consistent relationship between nitrogen level and scald incidence has occurred but high nitrogen has been associated with low susceptibility to Jonathan spot.

Magnesium

The role of magnesium in storage disorders, particularly pit, is still unresolved. Arguments for a primary role come from observations that:-

- 1) Magnesium in irrigation water and tree sprays of magnesium have increased pit.
- 2) The value of the correlation coefficient is often greater when the ratio of Mg/Ca rather than calcium alone is used as one variable.
- 3) The content of magnesium is higher in pit lesions than in sound tissue from the same fruit.
- 4) Under low calcium nutrition magnesium level in fruit is increased.

Against these arguments are:-

- (1a) Bitter pit affected fruit is not higher in magnesium level than sound fruit of the same size from the same tree.
- (2a) Using partial correlation analysis to hold all other major elements and mean fruit weight constant, the Mg: pit correlation is seldom significant and then may be either positive or negative.
- (3a) Under high ammonium nitrogen, magnesium level is depressed but pit incidence is increased.
- (4a) If pre- or post-harvest treatments of combined calcium and magnesium are applied to fruit, there is no reduction in the effectiveness of the calcium.

In pot experiments, increasing the magnesium level in the medium depressed calcium and increased protein nitrogen and these effects may constitute the mechanism of the magnesium effect on pit.

An alternate explanation may be in the hypothesis advanced by True as early as 1922. "Under calcium starvation condition magnesium comes closest to replacing calcium but fails to be effective partly because of the greater permeability of magnesium pectate but chiefly because of the ultimately toxic action of magnesium ions when they penetrate to the inner cell structure." If this hypothesis applies, then the actual level of magnesium is irrelevant so long as it is above a certain threshold.

Calcium and magnesium are always positively correlated in fruit and usually very highly significantly, but under conditions when both are declining in fruits, calcium falls more rapidly and magnesium may be in sufficient quantity to become toxic when calcium has fallen to critical levels. In the other direction, so long as the calcium was adequate to fill all necessary loci, high magnesium would have no effect. In this situation, while a correlation of pit and calcium would be found, none would appear with magnesium.

In breakdown the role of magnesium is unresolved. On some occasions after partial correlation treatment, magnesium and breakdown have been significantly (positive) correlated but there are frequent exceptions. No consistent differences

between sound and affected fruit in the level of this element have been found. Magnesium treatments have not increased breakdown.

Scald sometimes shows a negative correlation with magnesium level but no relationships have been found with Jonathan spot.

Potassium

The influence of potassium on bitter pit has features in common with magnesium but it is less clearly defined. High potassium fertilization and potassium sprays have been recorded as increasing pit but there are numerous exceptions. A K/Ca ratio has often shown higher values of correlation coefficient with pit than the simple Ca value.

On the other hand when partial correlation analysis is applied and the other major elements and mean fruit weight are held constant no example of a significant relationship between pit and potassium has been found.

In pot culture experiments, increased potassium in the fruit has not been associated with increased pit incidence unless the calcium level is very low, and then the increase is small. Affected and sound fruit from the same tree have usually similar potassium levels.

High potassium is associated with high acid levels which is suggested by some as a factor affecting pit. However, high potassium and acid levels are both characteristic of light crop fruit which is also associated with low calcium level. When the effect of relative crop level is eliminated by using mean fruit weight as an independent variable in partial correlation analysis, potassium and pit are not significantly correlated but calcium and pit are. Potassium treatment sometimes increases protein nitrogen levels.

For breakdown, however, a significant negative correlation with potassium sometimes survives partial correlation analysis. There is a tradition that potassium manuring reduces breakdown though this has not been proved experimentally. If there is any potassium effect it is interesting that it should be in the opposite direction for pit and breakdown whereas calcium operates in the same direction.

No associations with scald or Jonathan spot have been proved.

Phosphorus

Evidence for the association of this element with bitter pit is limited and contradictory. In our experience any relationship seldom remains significant after partial correlation although some examples of very highly significant positive correlation have occurred.

The relationship with breakdown appears to be a little more probable. The relationship in this case is usually negative and is sometimes highly significant in partial correlation analysis. There have been indications that increased phosphorus may tend to mitigate the effects of excess nitrogen. No consistent differences have been found between phosphorus level in sound and disordered fruit from the same tree.

No associations with scald and Jonathan spot have been noted.

Boron

In the 1930s, following the recognition of boron deficiency symptoms in apples, many people experimented with this element but most failed to find any consistent effects on storage disorders, even when tree sprays were applied over a period of years. In some cases small but significant reductions in pit occurred, but treatment also reduced fruit size and much of the effect could be attributed to this.

More recently interest has revived in this element but again spray treatments of either boron alone or in combination with calcium/NAA/zinc failed to show a significant boron effect. Soil treatment with boron has in some cases been noted to be followed by a marked decline in pit susceptibility (but no effect on breakdown) but nothing has yet been proved.

Effects of boron treatment on breakdown, scald or Jonathan spot have usually been absent.

Zinc

There have been a few reports of increased pit following treatments with zinc but equally numerous examples of no effects.

Other Elements

No response to treatment with Mn, Co or Fe has been found. Experiments with a combination of a wide range of minor elements have shown that they do not significantly increase the effectiveness of calcium.

Discussion

It is difficult to get calcium into the fruit and to prevent its mobilization and translocation from the fruit into the

aves. the amount getting into the fruit depends on nearby vegetative competition. Calcium will not move out of the leaves and into the fruit so that tree sprays with calcium must fully wet all fruit. Maximum absorption of calcium from sprays occurs on the shoulders and basal rim of the fruit, which is the usual area for development of pit. The big step that could be taken to reduce storage pit would be to ensure that fruit from light crop trees was not harvested for export; large attractive apples are much more likely to develop the disorder.

The role of calcium on the incidence of low temperature breakdown is not clear, particularly as much reported work did not consider fruit size variations. In Tasmania calcium has been found to reduce LTB in Cox and Sturmer when applied as a post-harvest dip, however, Jonathan did not respond. Work by Palmer at Scoresby indicated a synergism between calcium and phosphorus in reducing breakdown, the combined effect being large.

In general it is difficult to change the composition of apple fruits and what changes can be made have had no clear effects on disorders.

PRUNING AS THE CRITICAL FACTOR IN CALCIUM NITRATE SPRAY
CONTROL OF BITTER PIT IN GRANNY SMITH APPLES

S.E. Hardisty*

Factors which are well recognized by horticulturists as making fruit more likely to pit are fruit size, nutrition, drought conditions during the growing period, 'off' crop, pruning, and immaturity. Of these factors, immaturity is generally the most well known.

Experiments conducted in Western Australia in 1970 and 1971 and subsequent observations in 1972 demonstrated that the presence or absence of vigorous vegetative growth adjacent to fruit appears also to be of major importance. This suggests that non-pruning is an important first step to be taken to eliminate bitter pit from early harvested Granny Smiths for export and that for bitter pit trials the selection of heavily pruned orchard sites should be avoided.

Introduction

In the summer of 1970 the following observations were made at Stoneville Research Station (40 km east of Perth) from bearing trees and they were followed up by a few empirical measurements:

- (1) Pitted fruit had generally much lower calcium levels than sound fruit.
- (2) There was wide variation in calcium content of individual apples receiving similar treatment on the same tree. The range was from 26 p.p.m. to 72 p.p.m. on a fresh weight basis.
- (3) The main factor operating with fruit calcium levels on the same tree appeared to be the closeness of apples to strong vegetative growth.
- (4) A single preharvest spray of calcium nitrate applied a few hours before picking was apparently sufficient to change the incidence of pit from 17 per cent in fruit from the untreated half to 5 per cent pit from the half of tree receiving the preharvest application.
- (5) The therapeutic effect of calcium sprays appeared to be associated with small increases in calcium in the skin and not with an overall increase in calcium in the flesh of the apple. This suggested that pit liable fruit could be

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carried over a threshold value by small quantities of calcium absorbed into the skin of the fruit, rather than by a buildup in calcium in the flesh.

- (6) Some empirical measurements carried out on fruit showed that the calcium level was substantially higher in sound apples as compared to pitted fruit. These measurements are given in Table 1.

TABLE 1

The Calcium Levels on a Fresh Weight Basis of Fruit
(with samples of 10 apples) taken from Two Separate
Trees which Received Different Spray Treatments

Treatment	Pitted fruit	Sound fruit
1 Ca NO ₃ spray applied in Dec.	28 p.p.m. (range 23-33 p.p.m.)	41 p.p.m. (range 29-48 p.p.m.)
4 Ca NO ₃ aprays applied Dec. - early Feb. period	25 p.p.m. (range 19-32 p.p.m.)	35.6 p.p.m. (range 29-43 p.p.m.)

These observations and incidental measurements suggested that pruning, by inducing a current season response in vegetative vigour, may well have a marked effect on calcium content and in turn, bitter pit. The experiments recorded herein, undertaken between the dormant season of 1970 and 1972, were made to determine these effects.

Experimental Methods and Results

Pruning is well known to promote vigorous vegetative growth. Experiments were undertaken on Granny Smith apple trees at Stoneville Research Station where, during the 1970 dormant season heavy pruning cuts were made and tagged with coloured plastic string. Fruit was selected at harvest adjacent to vigorous current season's growth and in many instances but not always the selection was made close to the tagged pruning cuts. Other fruit was selected for comparison from along unpruned laterals and from fruiting spurs. Only light amounts of foliage was associated with this type of fruit. This fruit was stored for 2 months and measurements were then carried out to determine percentage pit development and calcium content (Table 2).

TABLE 2

The Effect of Near Vegetative Growth on Pit Susceptibility
of Fruit from a Single Tree, the Fruit being Picked
on March 17th

Selection of fruit	% pit after cool storage	Average calcium content on a fresh weight basis of a 10-apple sample
Fruit borne on unpruned laterals and spurs with light adjacent foliage growth	8	44 p.p.m. (range 31-62 p.p.m.)
Fruit adjacent heavy foliage growth normally close to severe pruning cuts	52	29 p.p.m. (range 23-37 p.p.m.)

The data of Table 2 applies to a pick on March 17th. An earlier pick was carried out on March 11th. The fruit was rated for pit but no calcium levels were undertaken. It is worth recording that in this March 11th pick, pit increased from 40 per cent in fruit in unpruned laterals to 80 per cent in fruit selected adjacent to heavy vegetative growth.

An interesting further observation on the effect of pruning and subsequent heavy vegetative growth was made at Newlands (200 km south of Perth) in 1972. At this site the growers' pruning techniques of detailed heavy pruning caused upright shoot extension and vigorous leaf growth. In turn this produced an effective barrier which sheltered the fruit from calcium sprays. Fruit was picked from six of these pruned trees from the sheltered positions inside the trees which had been sprayed three times with calcium nitrate using a semi-concentrate sprayer. This fruit later developed 40 per cent pit. By comparison, unsheltered fruit from neighbouring trees similarly sprayed was relatively free from pit.

These observations and results need to be considered in the light of earlier trials with trees of more open foliage which showed that concentrate sprays can adequately control pit if the spray reaches the fruit.

Conclusions

The results and observations recorded suggest that pruning, with its effect on vegetative growth, affects the calcium content of apples. This in turn appears to be linked to the

level of bitter pit development in storage. It is suggested further that there may well be a mechanical as well as a physiological effect of pruning, in that the vigorous vegetative growth associated with pruning prevents calcium sprays reaching the fruit.

It is accepted that fruit immaturity is of critical importance in the development of bitter pit, but with the Granny Smith crop approaching 3 million bushels in Western Australia, an early start to harvest is essential, and this has coincided with a pit susceptible period. Therefore it is suggested that our efforts to avoid pit in early export fruit could well be directed towards the selection of fruit from mature unpruned trees.

Discussion

Dr Martin said that a complex of calcium, respiratory behaviour and protein nitrogen is intimately linked with pit susceptibility but protein nitrogen has not been looked at on a fruit region basis as calcium had been.

Tree pit in Granny Smith apples is rare and hard to induce, storage pit is the one of importance. Correct tree management and elimination of light crop fruit would almost ensure pit free fruit for export.

The use of Alar was not considered to be of importance in reducing pit. It operates by reducing length of internodes and not necessarily reducing leaf area. Dr Martin added that Alar increases calcium and reduces pit by reducing fruit size, which is an inefficient result with carryover effects into the following season.

THE EFFECT OF PREHARVEST CALCIUM NITRATE SPRAYS ON THE
DEVELOPMENT OF SUPERFICIAL SCALD OF STORED APPLES

S.E. Hardisty*

In 1970 a number of experiments were undertaken in Western Australia on the use of preharvest calcium nitrate sprays for bitter pit control in stored Granny Smith apples. During the course of these experiments it was noticed that the CaNO_3 treatments also had an effect on the subsequent development of superficial scald in the stored fruit. In one trial, a single calcium nitrate spray a few hours before picking resulted in a scald level of 8 per cent as compared to 18 per cent for unsprayed fruit. It has been long thought that calcium nitrate sprays have a synergistic effect when added to post-harvest applications of D.P.A. and ethoxyquin for scald control. The observations in 1970 however indicated that CaNO_3 may have a role in its own right and trials were carried out in 1971 to test the effects of pre-harvest calcium nitrate applications on the subsequent incidence of superficial scald during short-term storage of Granny Smiths.

These 1971 trials were carried out using 60 trees (6 replicates of 10 treatments) at Newlands - 200 km south of Perth. Harvested apples were stored at 1°C and checked for scald after 2 months cold storage and a further week of common storage. Details of the spray treatments and the results are given in Table 1.

Although the harvesting dates were somewhat earlier than desirable for an experiment on superficial scald, the results clearly indicate the effect on scald of applying calcium nitrate before harvest. Except for a spray schedule applied early- to mid-season all calcium nitrate treatments significantly reduced the amount of superficial scald developing in the stored fruit.

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TABLE 1

Level of Scald on Granny Smiths after 2 Months Cool
Storage expressed as the Percentage of Apples
Developing Superficial Scald

Treatments†	Harvested on 10/3/71	Harvested on 17/3/71	Harvested on 24/3/71
Controls (No CaNO ₃ sprays)	37	12	24
1 pre-harvest CaNO ₃ spray on 17.3.71	Not applied	5.8**	3***
3 CaNO ₃ sprays in Dec.-Jan.	31 N.S.	8*	3***
3 CaNO ₃ sprays in Feb.-March	17*	6**	4***
3 CaNO ₃ sprays in Dec.-Jan. + 1 pre-harvest spray on 17.3.71	Not applied	6**	3***

† Calcium nitrate was applied at 8 lb/100 gal.

N.S. No significant change.

* ** *** Significant change.

Although these are of interest it is not suggested that pre-harvest CaNO₃ sprays in themselves should be considered as adequate in preventing scald.

A SIMPLE TEST OF D.P.A. CONCENTRATIONS IN POST-HARVEST DIPS

J.B. Watkins*

Diphenylamine (D.P.A.) applied as a post-harvest dip is an effective control for superficial scald on apples and pears when used at the recommended concentration. As there is a continuous loss of D.P.A. from the dip, D.P.A. must be replaced periodically to maintain an effective concentration range. When using a 2000 parts per million (p.p.m.) (0.2%) dip, it is recommended that D.P.A. is added when the concentration has fallen to 1500 p.p.m. Similarly, when using a 1500 p.p.m. dip, D.P.A. is added when the concentration has fallen to 1000 p.p.m. A 2000 p.p.m. dip is recommended for early picked Granny Smith and Delicious apples and control atmosphere storage or polyethylene liner storage of these varieties. A 1500 p.p.m. dip is recommended for Delicious apples, early Packhams pears and late Granny Smith apples.

This paper describes a simple test procedure to indicate when the dip concentration has fallen by 500 p.p.m. and includes formulae for calculating the amount of additional 'Scal-Dip' (25% D.P.A. emulsion) to restore the original concentration.

The following materials are required to carry out the test.

- 2 eye droppers
- 2 glass or plastic measures, tapered, calibrated at 4 ml, 5 ml and at intervals to 50 ml
- Sodium nitrate solution (10 g sodium nitrate in 20 ml water)
- Sulphuric acid solution (50 ml of water plus 50 ml of concentrated acid)
- 2 small test tubes ($\frac{1}{2}$ " diam., 4" long) and stoppers.

Test Procedure

Using one of the glass measures, take 5 ml of the dip to be tested. If the original dip concentration is 1500 p.p.m., add water to the 5 ml sample to make a total of 30 ml. If the original concentration is 2000 p.p.m., dilute the 5 ml dip sample with water to make a total of 45 ml. Using an eye dropper, add two drops of the nitrate solution followed by four drops of the diluted sample to a test tube (the second eye dropper is used for adding the four drops of diluted dip sample), then using the second measure, add 4 ml of the acid solution to the mixture of diluted sample and sodium nitrate solution. Place a stopper in the tube and shake vigorously

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For a few moments. The blue colour which develops is compared with the colour standard.

Colour Standard

The colour standard developed is based on the B.D.H. indicators Bromo-thymol Blue pH = 6.0-7.6 (0.04%) and Bromo-phenol Blue pH = 2.8-4.6 (0.04%). It is made in the following manner: 50 ml of potassium dihydrogen phosphate (0.2M) plus 46.85 ml of sodium hydroxide (0.2M) are mixed and made up to 200 ml with water to form the basic buffer solution.

The standard colour solution is made by mixing 1.6 ml B.D.H. Bromo-phenol Blue and 0.4 ml of Bromo-thymol Blue. The mixture is diluted to 100 ml with the basic buffer solution.

This colour standard is used to determine when the test dips of D.P.A. have fallen to a level requiring addition of D.P.A. concentrate. The colour standard may be kept for two weeks before replacement.

Addition of D.P.A.

Test samples are taken at regular intervals from the dip-tank until the test sample approximates the standard colour. D.P.A. must then be added to restore the initial concentration. To calculate the amount of D.P.A. concentrate required, first estimate the volume, in gallons, of dip lost from the tank. Call this volume 'y' gallons. If the original volume was 'x' gallons then the number of gallons of 'Scal-Dip' to be added to restore the original strength and volume is $\frac{x + 2y}{500}$ gallons of 'Scal-Dip' in 'y' gallons of water for the 1500 p.p.m. dip and $\frac{x + 3y}{500}$ gallons of 'Scal-Dip' in 'y' gallons of water for the 2000 p.p.m. dip.

Example

Suppose the original volume was 400 gallons of 1500 p.p.m. D.P.A. when the level fell to 1000 p.p.m., suppose 50 gallons of dip have been removed by the apples. Then the 'Scal-Dip' required is $\frac{400 + 100}{500} = 1$ gallon of 'Scal-Dip' in 50 gallons of water.

Similarly, for 400 gallons of a 2000 p.p.m. dip, the amount of 'Scal-Dip' to be added when the dip concentration is 1500 p.p.m. and 50 gallons of solution have been lost would be $\frac{400 + 150}{500} = \frac{550}{500} = 1.1$ gallons of 'Scal-Dip' in 50 gallons of water.

Discussion

The test described is easy for unskilled people to use and should be generally adopted. Concern was expressed at the number of post-harvest dips which are run below the nominal concentration, and the difficulty packing houses have in maintaining recommended levels. Instances were quoted of TBZ dips being at 125 p.p.m. instead of the nominal 1000 p.p.m. and one instance of a DPA dip having no DPA at all.

ANTHOCYANIN ACCUMULATION AS A MATURITY INDEX FOR RED APPLES†

D.J. Chalmers, J.D. Faragher and J.W. Raff*

Introduction

It is generally known that a strong relation exists between late season redness and maturity of apples. This is one of the indexes of maturity in early-to mid-season red varieties of apples used in practice by fruit growers.

Attempts to make more objective use of the property of total red pigment (anthocyanin) in apple skin to predict or define a date of maturity have failed (Hesse and Hitz 1938), because changes in the regulatory status of anthocyanin synthesis due to maturity have not been separated from seasonally varying factors affecting the anthocyanin level. Where workers have reported the annual study of anthocyanin accumulation (Creasy 1968; Faust 1964, 1965), it is clear that although the time course of anthocyanin accumulation is very similar from year to year, there are large differences in seasonal potential for anthocyanin synthesis.

In these data the seasonal differences in total anthocyanin level at the onset of rapid anthocyanin accumulation are such that the same levels in different seasons may be reached over a 10-20 day period. If total levels at this time are used to estimate maturity, a 10-20 day difference is indicated between seasons. Much of this variation is due to limitations of seasonal factors on pigment synthesis and little real difference in maturity exists.

It is clear that an equilibrium exists between synthesis and degradation of anthocyanin in immature fruit when the level of anthocyanin fluctuates under the control of light and other environmental factors (Creasy 1968; Chalmers and Raff 1972). However when the fruit matures, accumulation of anthocyanin begins to occur regardless of the light treatment, as long as the requirement for high energy light in the photosynthetic wavelengths is met. At this stage the rate of synthesis of anthocyanin exceeds the rate of degradation, but it is not clear whether this is due to inactivation of the degradative enzyme(s), removal of the synthetic reaction products from the region of degradative metabolism, or a higher rate of synthesis. Nevertheless, for example, one can predict that a decrease in the light intensity would cause a decrease in the level of

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anthocyanin in immature fruit, while accumulation would continue in mature fruit.

Therefore by using this change in the regulation of anthocyanin accumulation as an indicator, one should be able to objectively predict maturity in any season regardless of variations in the absolute level of anthocyanin.

This paper reports the study of changes in the potential of apple skin to accumulate anthocyanin during maturation and the relation between the 'cross-over' from degradation to accumulation in different light environments and arbitrarily determined dates of maturity.

Material and Methods

The apples used in these experiments (cv Jonathan) were grown in the orchard at Scoresby Horticultural Research Station, southern Victoria. Two experiments were carried out to study maturity and anthocyanin accumulation and the 'cross-over' between degradation and accumulation stages.

Where the effect of maturity on the rate and potential for anthocyanin synthesis was studied the fruit were randomly harvested from shaded positions on the trees so that they were completely green when initially exposed to sunlight. Fruit were harvested at weekly intervals from a date approximately 6 weeks before the estimated harvest date. Of the sample taken each week half were exposed to sunlight under a muslin screen and sprayed occasionally with water to prevent sunburn. The remaining half of this sample was stored at 0°C for a week and then exposed to sunlight in the same way as the first half. This was to allow for variations in pigment development due to daily and weekly fluctuations in light intensity. A random sample of 10 fruit was taken daily for up to 11 days and the anthocyanin level determined on skin discs from two groups of 5 fruit as described previously (Chalmers and Raff 1972). The results reported for skin pigment content at any one time of exposure are the mean of two groups of five fruit at two exposures in consecutive weeks. Results are expressed in nanomoles idaein cm^{-2} of apple skin, determined from the molar extinction coefficient (3.43×10^4) of idaein in 1% methanolic HCl (Siegelman and Hendricks 1958).

To determine the 'cross-over point' between anthocyanin degradation and accumulation, 30 groups (five replicates x six harvests) of four fruit of similar size, colour, location on the tree and all well exposed to light were selected. In each group of four fruit the four shading treatments described below were allocated at random. 'Sarlon' plastic-mesh shade cloth was formed into tetrahedral bags (of 20 cm edge) with as little overlapping of the shade-cloth as possible. The

Bags were sprayed with a silver paint to avoid heating of the bags and consequent burning of the fruit. They were attached around the developing fruit in early January, 8 weeks before the expected time of harvest.

Three densities of shade cloth were used. These gave 22, 37 and 42% of full sunlight, which was the control. At weekly intervals commencing 2 weeks after the bags were attached, five groups of four differently shaded fruit were removed and the skin anthocyanin level determined using five discs of 1.5 cm diameter, taken from the zone of most intense colour, on each fruit.

Results

The data in Figure 1 shows the effect of maturity on the rate of synthesis and the potential to accumulate anthocyanin. The rate of anthocyanin synthesis appears to increase between weeks 1 and 4 but it is relatively uniform in fruit harvested thereafter. On the other hand the potential for accumulation of anthocyanin changes as the fruit matures. Until 3 weeks before harvest anthocyanin stopped accumulating quite abruptly after approximately 4-5 days exposure to sunlight. The maximum level of anthocyanin in fruit picked 5 weeks or more before commercial harvest date reached about 25 nmoles cm^{-2} or less 90 hours after exposure to sunlight began (Weeks 1-4, Fig. 1). However fruit harvested after this date (Weeks 5-10, Fig. 1) continued to accumulate anthocyanin for the duration of the experiment (200-250 hours).

Figure 2 shows the change occurring with maturity in the rate of pigment accumulation under control and shading conditions. The 'cross-over' between predominantly degradative and accumulative phases is clear.

In the unshaded control the level of anthocyanin was variable from week to week until 2 weeks before commercial harvest when rapid accumulation commenced and replaced the equilibrium state. When the fruit was shaded there was a drop in the level of anthocyanin (degradation) until 2 weeks before commercial harvest when accumulation began to occur. The decrease in red skin-colour was a function of the intensity of the shading treatment applied. In addition the 'cross-over' from degradation to accumulation was independent of treatment although in the treatment receiving 42% sunlight it was not so clearly defined.

Discussion

Our results show that changes in the potential to accumulate anthocyanin and in the regulation of accumulation occurred at a certain stage of maturity, about 2 to 3 weeks before commercial harvest of Jonathan apples at the Research Station (14th March).

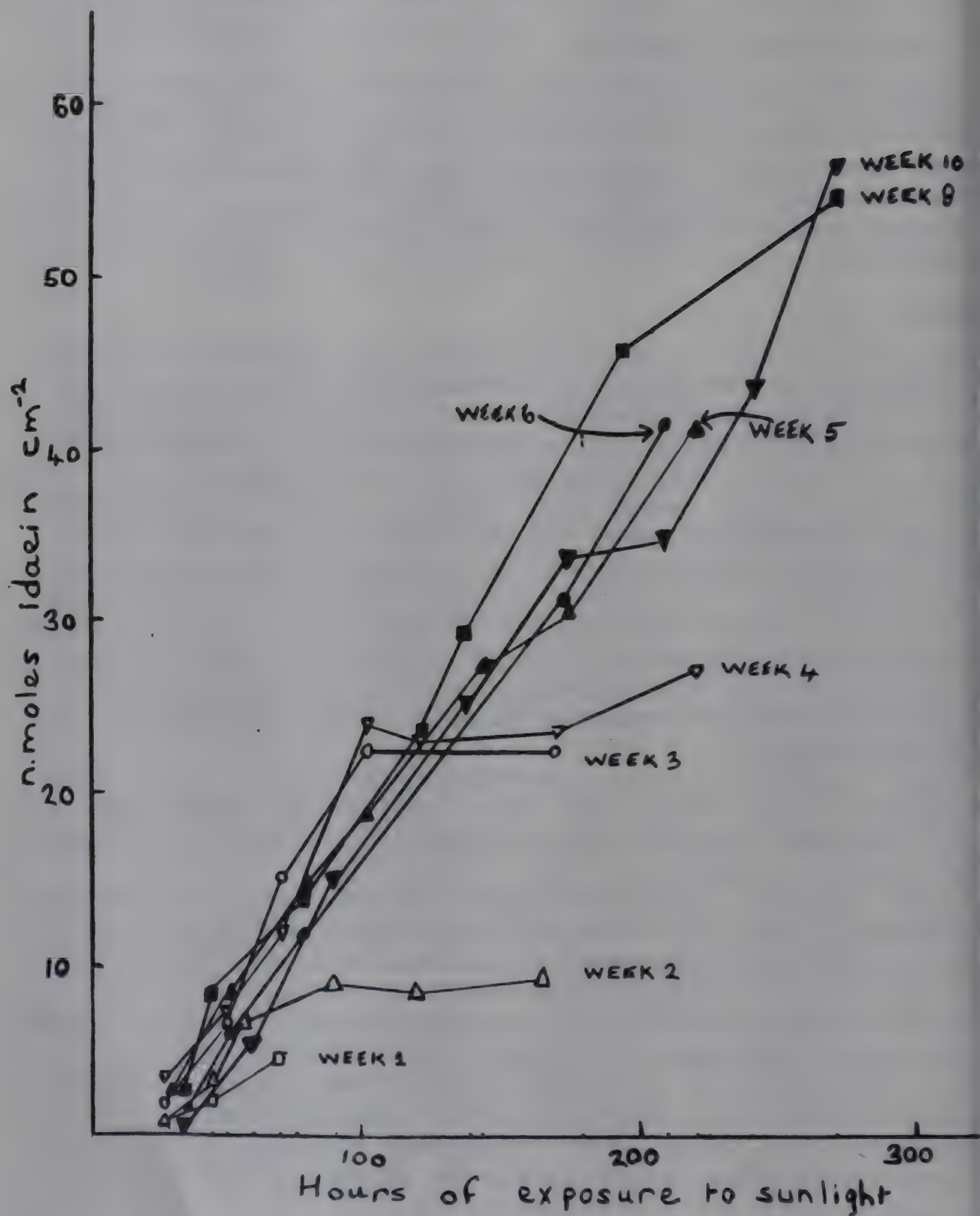


Figure 1. The rate and amount of anthocyanin accumulated by apples harvested at weekly intervals for 10 weeks (week 1 - week 10 from 21/1/72 to 27/3/72).

Faust (1965) suggested the difference between mature and immature red apples was that the endogenous rate of synthesis of anthocyanin was higher in mature apples. However, our data here (Fig. 1, weeks 3 and 4) and elsewhere (Chalmers and Raff, unpublished data) suggest the rate of anthocyanin synthesis may be higher in slightly immature apple skin and that the fundamental difference lies in the potential to degrade anthocyanin.

Chalmers and Raff (1972) suggested that anthocyanin accumulation was limited in immature fruit by the availability of galactose. The level of galactose is likely to fluctuate with light intensity and photosynthesis as the products of photosynthesis are rapidly converted to starch in immature apples and therefore the supply of hexose intermediates will depend on active photosynthesis.

Anthocyanadin, not commonly found free in plant tissues (Blank 1958), is probably rapidly metabolized in the absence of galactose but after the glycoside has been formed it is stable enough to be exported to the vacuole. When the rate of synthesis drops, perhaps due to lower light intensity, net transport of anthocyanin between the cytoplasm and the vacuole would be down the concentration gradient to the cytoplasm where it would gradually be metabolized. This leads to the equilibrium level of skin pigment shown in Figures 1 and 2 where the fruit was picked more than 2 weeks before commercial harvest. After this time the level of galactose is sufficient to allow accumulation of anthocyanin even in conditions of decreased light intensity.

The change from the equilibrium state in less mature fruit to accumulation in more mature fruit is apparent in both experiments. The date after which accumulation continues in Experiment 1 (Fig. 1) coincides with the time degradation ceases in Experiment 2 (Fig. 2). The most useful estimate of this stage of maturity is obtained from Figure 2. The rate of degradation of anthocyanin was proportional to the reduction of light intensity while later the rate of accumulation was inversely related. Therefore to obtain the clearest estimate of this 'cross-over' point a compromise of the best light intensity for anthocyanin degradation and accumulation needs to be found. According to our data this would be between 25 and 30% of full sunlight.

Both these methods gave simple estimates of the date of Jonathan maturity. However their value may be limited because of the relatively short notice that can be given of impending harvest date (2-3 weeks). We propose to extend this study of the potential of apple skin to accumulate anthocyanin to give a sharper and earlier 'cross-over' point between equilibrium

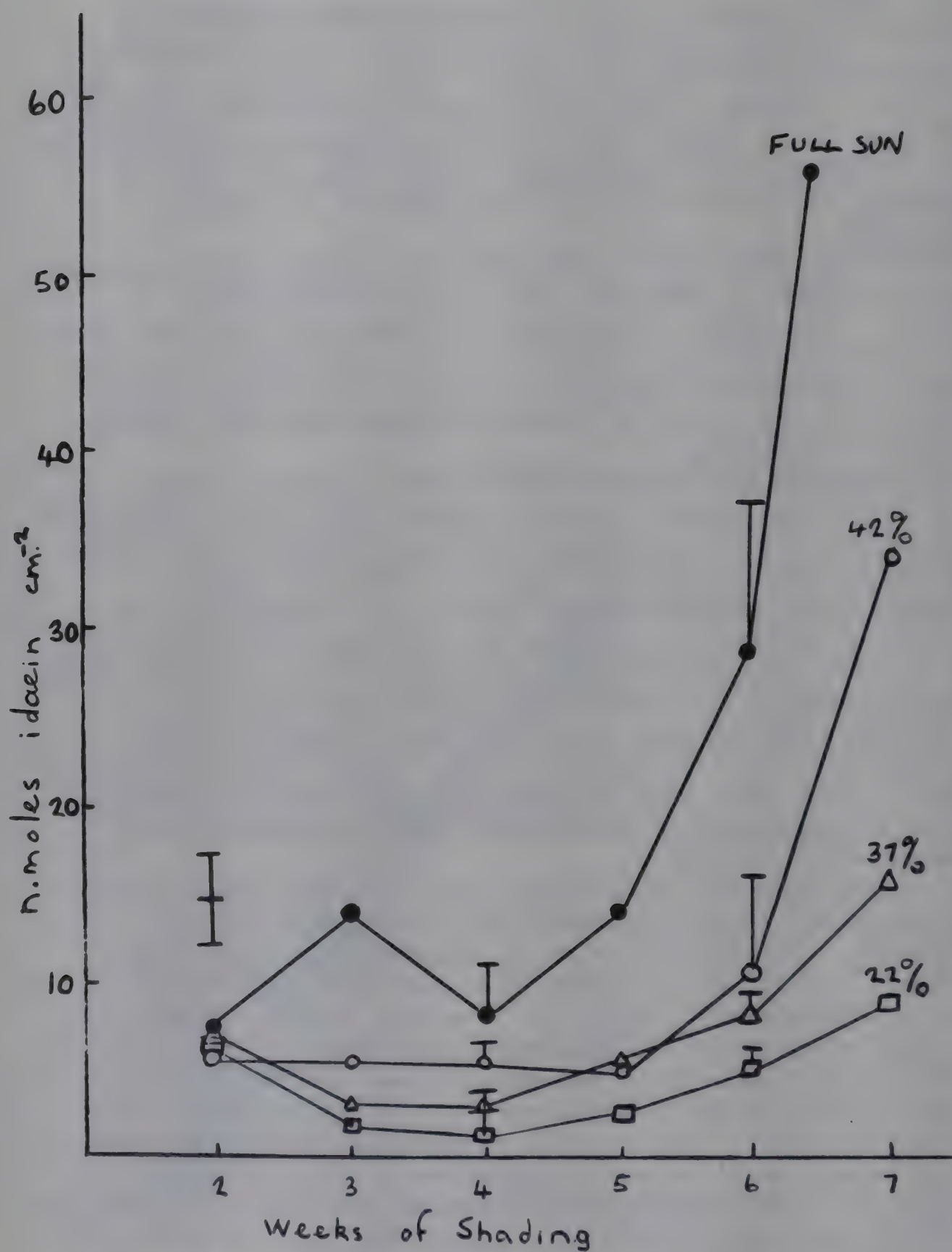


Figure 2. The effect of light intensity on the anthocyanin level of apples harvested at weekly intervals. (●) full sunlight, (○) 42% of full sunlight, (Δ) 37% and (□) 22%.

and net accumulation. Different light intensities and other environmental factors such as temperature may improve the methods used here.

Since maturity can be advanced by premature harvest (Smock and Neubert 1950) a ripening procedure giving a predictable advancement of maturity might be used to pretreat fruit to be surveyed for maturity. If the methods described here can then be used successfully to assess the maturity a useful advancement of this prediction might be made. In addition if these procedures can be used with harvested fruit controlled environments could be used to reduce variability.

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Discussion

Questions tended to suggest that difficult cases, such as full red Jonathans, might be beyond the method. The author was

confident it could be generally useful, although not to develop a colour card for use by growers and extension people, because the anthocyanin content varies seasonally so that the test is relative one for a particular year.

As with any method of this kind sampling is difficult, but a grower has a similar problem when making his decision when to pick from a range of maturities on any one tree.

PREDICTION OF THE OPTIMAL HARVEST DATE FOR THE JONATHAN APPLE

B.L. Tugwell*

The investigations referred to in this report are being carried out in cooperation with the Bureau of Meteorology in South Australia.

Introduction

For each apple variety there exists an optimum harvest date, and an optimal harvest period of several days either side of that date, during which the fruit should be harvested for long term cool storage. Jonathan apples picked earlier than 1 week before the optimal harvest date are immature, sour and of poor flavour, and will shrivel during cool storage. If harvesting is delayed more than 1 week after the optimal maturity the fruit is sweet and of very good flavour, but storage life is reduced due to the development of the storage disorders Jonathan spot and senescent breakdown.

In a review of guides for determining the maturity of apples for storage, G.D. Blanpied (1960) of Cornell University lists 19 guides to maturity. He suggests that there is no one guide which will tell when to start picking and that every guide at the growers' disposal should be used to determine when to start. Several of these guides are currently being used in South Australia.

In South Australia the main apple growing areas are located in an area of the Adelaide Hills 20 miles long by 10 miles wide. Eighty per cent of the crop is stored and consumed locally and 40% of the crop grown is the Jonathan variety.

A forecasting system has been developed to predict the optimal harvest date for the Jonathan apple in the Adelaide Hills. The predicted date is made available early in January and growers are also encouraged to observe the changes in ground colour of the fruit, and flavour changes in order to decide when to start picking for cool storage.

Predicting the Optimal Harvest Date

In reviewing the effects of weather and climate on the maturity of apples the World Meteorological Organization (1963) concludes that the number of days from full bloom to optimal maturity is fairly constant for a given variety under diverse climatic conditions, but slight seasonal variations in the length of period from full bloom to maturity may be caused by high or low temperatures during the first 3 weeks after full

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bloom. No consistent relationship was found between accumulated degree days and optimum harvest date for the last 8 weeks before harvest. Keeping quality, however, was shown to be associated with the weather during the last 2 months prior to harvest.

The optimal harvest date for Jonathan apples has been determined experimentally in South Australia since 1964 by harvesting fruit at weekly intervals and determining the storage life of the fruit when held at 32°F. Complete full bloom records were not available, but first green tip records were available and easier to determine.

Degree day totals were determined by the Bureau of Meteorology from mean daily temperature records at Mount Barker (1083' above sea level), the nearest observing station to the Adelaide Hills apple growing area. Base temperatures of 39°F to 46°F were used in the initial determination of degree day totals for the time between green tip and optimal maturity. The base temperature of 42°F was selected for simulating forecasts of optimum picking date for each of the seasons for which data was available. These simulated forecast dates were based on actual temperature accumulations to the 31st December followed by an estimate based on the assumption that mean temperatures would approximate the long term average from January 1st onwards. Since 1970 the forecasts have been released to apple growers as a guide to the optimal harvest date for Jonathans.

Simulated Forecasts for Lenswood

Season	1964	1965	1966	1969	1970	1971	1972
Green tip	17.9.63	8.9.64	15.9.65	16.9.68	1.10.69	24.9.70	20.9.7
Degree days over 42°F required for maturity	3404	3404	3404	3404	3404	3404	3404
Accumulated to Dec. 31st	1889	1571	2037	1609	1621	1516	1577
Carry-over	1562	1880	1414	1842	1783	1886	1827
Forecast optimum	7th March	23rd March	1st March	21st March	20th March	24th March	20th March
Assessed optimum	6th March	24th March	3rd March	17th March	25th March	25th March	24th March
Error	1 day	1 day	2 days	4 days	5 days	1 day	4 days

In issuing the forecast to apple growers two other factors are taken into consideration. A considerable variability in mean temperature can occur over the hilly apple growing areas. Maximum temperatures generally decrease at the rate of 5°F per 1,000 ft increase in altitude. The World Meteorological Organization considers that the average retardation in maturity of fruit trees in North America is 1 day for every 101 feet increase in altitude and 4.6 days for every degree latitude to the north. The apple growing area in the Adelaide Hills varies in altitude from 1,800' at Forest Range to 800' at Blackwood.

The forecast optimal harvest date is given for Lenswood (1,400') and recommendations are adjusted for areas of higher or lower altitude. The optimal harvest date for Jonathans at Blackwood is about a week earlier than the predicted date for Lenswood.

The maturity of the Jonathan apple is also affected by the crop load the tree is carrying. Trees carrying a 'light' crop may be ready to harvest up to 2 weeks earlier than trees carrying a 'full' crop. The maturity forecast applies only to trees carrying a 'full' crop since this fruit is the most suitable for long term cool storage. Growers are advised to harvest fruit from young trees and 'light' crop trees up to 2 weeks before heavy cropping trees.

The forecast harvest date provides an advance warning to the grower so that he can harvest as much fruit as possible during the optimal harvest period of 2 weeks.

A ground colour chart is supplied to growers as an additional guide to the maturity of their fruit. When the ground colour of the fruit changes from green to yellow green the fruit is considered to be at the optimal maturity for cool storage.

A method of maturity forecasting based on accurately assessing the first stage of development of the stem cavity of an apple (T stage) is also being investigated at the Lenswood Research Centre. Karl Stoll at the Swiss Research Station for Horticulture at Wädenswil has shown that the time interval from the T stage to the optimal harvest date shows only minor variations from year to year in the same locality. This method is claimed to take into account both plant and climatic factors such as temperature, location, soil type, rootstock and cultural treatments which are not considered by forecasting on temperature alone.

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Discussion

The base temperature of 42°F was selected as being that at which vegetative growth ceased.

In general, the author was satisfied that this method of predicting optimum harvest date was adequately reliable in the Adelaide Hills area.

CHEMICAL REGULATION OF MATURATION AND RIPENING*
J.B. McGlasson

Three factors have led to a renewed interest in this topic. They are: (1) the marketing and economic circumstances which are leading to a reduction in the range of cultivars of some fruits being grown and the interest in more efficient harvesting methods; (2) the advent of synthetic growth regulating chemicals such as Alar and Ethephon; and (3) the development of physical methods for measuring endogenous growth regulators in plant tissue. This review will concentrate mainly on recent advances associated with the last two of these factors. Progress in applied work with chemicals has been reviewed by Wittwer (1971) and Looney (1972).

It is a reasonable assumption that under normal growing conditions the growth, development and senescence of plant organs is controlled by growth regulators. The known natural growth regulators may be divided into five classes; auxins, cytokinins, gibberellins, gaseous hydrocarbons (principally ethylene) and abscisins. A working hypothesis is that the balance between these different hormones determines the kinds of physiological responses we observe. The importance of this balance was illustrated by Skoog and Miller (1957) who showed that depending on the relative amounts of auxin and kinetin added, aseptic tobacco pith tissue cultures could be induced to undergo only cell expansion, only cell proliferation, both cell proliferation and expansion, or development of roots and buds. By analogy correlation of the endogenous levels of each of the classes of regulators with stages in the development of fruit would thus be expected to help indicate some of the processes being regulated.

Most of the earlier measurements of the levels of endogenous regulators relied on bioassays which were laborious and time consuming. The chief advantage of bioassays is their potentially great sensitivity since growth regulators are present in plant tissues in only minute amounts. However, separation methods need to be very thorough because contamination from other plant constituents may severely interfere with bioassays. Recently, physical methods have been developed with sensitivities which, in some cases, equal or exceed those of bioassays (Powell 1972). Gas chromatography using a flame ionization detector is now well known for assaying ethylene and it is possible to measure as little as 0.2 picomole in a 5 ml sample of air. The same detector can be used for assaying volatile derivatives of auxins, abscisic acid (ABA) and the gibberellins

to less than 10 picomoles per injection. The use of an electron capture detector has enabled quantitative measurement of less than 0.1 picomole of ABA and the recently developed alkali detector promises to be useful for measuring auxins and cytokinins down to 10 picomoles per injection provided that sufficiently volatile derivatives can be produced quantitatively. These physical methods also have the advantage that they can be coupled with mass spectrometry to assist with the identification of growth regulators (MacMillan and Pryce 1968).

Despite these advances in physical methods of measurement there are still considerable problems associated with the extraction of growth regulators from plant tissues. These include the difficulty of ensuring high levels of recovery, achievement of adequate separation from interfering compounds, avoidance of artifacts and quantitative derivatization of the growth regulators. In addition some of the growth regulators occur as glucosides or as other derivatives. Initial alcohol or acetone extracts are usually prepared for the acidic regulators. The free acids are then recovered by partitioning into an organic phase under acidic conditions. Appreciable amounts of the neutral forms of regulators such as the gibberellins and ABA which frequently occur as glucosides may be lost unless the neutral fractions are examined further.

Given that we can or will be able to measure directly and accurately the levels of the various growth regulators in fruits, we may pose the question, do the levels of extractable regulators give a true indication of their physiological importance?

There are many published accounts of measurements of extractable auxin levels in fruits (Luckwill 1959; Nitsch 1970) and in general, changes in extractable auxins have not been well correlated with definable stages in fruit growth except during the initial setting period after pollination. More recently however, the levels of some of the other hormones have been rather better correlated with particular events, e.g. in cotton fruit ABA levels increased markedly during abscission and dehiscence (Addicott and Lyon 1969).

In the case of the natural auxins the levels in a particular tissue have been shown to be regulated by alterations in transport, enzymic destruction and conversion to inactive forms. The same is also true of the gibberellins, ABA and the cytokinins. The regulation of ethylene levels is probably the simplest; it is only necessary to control its synthesis since it is a gas and readily diffuses from the tissue.

From the large volume of literature briefly alluded to the answer to the question whether measurements of extractable

regulators *per se* are physiologically meaningful would seem to be generally no. What, then, are the alternatives?

Recent work at Adelaide, North Ryde and in the U.S.A. suggest at least two potentially useful approaches to the problem. One approach is to study the metabolism of the regulators in plant tissue. Rappaport and others (e.g., Nadeau and Rappaport 1972) have investigated the metabolism of gibberellin in relation to developmental changes in plant tissues. In their work radioactively labelled gibberellin was supplied to the tissue and its conversion to other compounds studied. The amounts of regulator added can be varied from levels which have little physiological response. The approach at Adelaide and North Ryde has been to treat developing fruit with compounds which alter the rates of maturation or ripening and to attempt to relate these responses to changes in endogenous levels of the various growth regulators. During 1971-2 Dr N.E. Looney and I applied Alar and Ethephon to the Halehaven and Fragar cultivars of peaches at five times during stage II of fruit growth. Both compounds applied early in stage II advanced commercial maturity. These compounds appeared to hasten maturation by stimulating the rate of development during stage III rather than by hastening the onset of stage III. We also found that soon after treatment Ethephon increased ethylene evolution by the fruit but Alar did not. Alar did, however, affect ethylene production by fruit harvested during stage III.

Our hope was also to measure ABA, IAA and GA₃ levels in the peaches during development. We have learned a lot about the pitfalls in hormone analysis and we are only now obtaining satisfactory data for ABA.

Coombe and his colleagues at Adelaide have studied the responses of developing grapes to treatments with ethylene, auxins and ABA (Hale 1968; Hale, Coombe and Hawker 1970; Coombe and Hale, unpublished data). Application of the synthetic auxin benzothiazole-oxyacetic acid (BTOA) was found to delay stage III, while ethylene applied before the start of stage III also delayed ripening yet when ethylene was applied 1 week later ripening was promoted. The delay in ripening obtained by early application of ethylene was interpreted as an effect on auxin transport. Obviously grapes produce only small amounts of ethylene throughout their development suggesting that normally ethylene plays only a minor role in their development. The most recent work at Adelaide indicates that ABA may also play a role in the stage II-stage III transition in grapes. Coombe and Hale (1972) found that ABA levels rose significantly about 1 week before berry softening could be detected and further, that applications of ABA advanced the onset of stage III. An increase in ABA during maturation may be fairly general (e.g., tomatoes,

Dörffling 1970; cherries, unpublished data by R. Rudnicki).

Marei and Crane (1971) have carried out detailed studies with figs. In this fruit ethylene appears to be the major hormone controlling growth during stage II-III. Application of 245-T was earlier shown to stimulate growth of fig fruits but this effect has been shown to be due to auxin stimulated ethylene production (Maxie and Crane 1967).

In contrast to stone fruits, application of Alar to apples and pears delays ripening (Looney 1972). According to Looney (1968, 1969) the action of Alar in apples and pears may be to suppress the rise in endogenous ethylene production which is considered to trigger the respiratory climacteric in these fruits without affecting other attributes of maturity. This concept of the action of Alar was supported by observations that maturity indices such as changes in soluble sugars and acidity were not greatly affected. As discussed by N. Veinbrant in his paper the effect of Alar on physiological disorders in apples has not assisted in clarifying its effects on maturity. According to Looney (1972) no compound has been found that will advance or delay all aspects of maturity in apples equally or even alter the time course of growth without affecting final fruit size. While Alar has been useful experimentally it has proven to be of only marginal horticultural value for pears.

Banana, tomato and citrus fruits have also been used extensively as experimental material for studies with growth regulators. Treatment of whole tomato and citrus fruits with gibberellic acid delays the loss of chlorophyll and symptoms of aging (Coggins and Lewis 1965; Dostal and Leopold 1967). In tomatoes the development of lycopene is also delayed but there is little or no delay in the onset of the respiratory climacteric. In pilot experiments at North Ryde developing tomato fruits showed little response to Alar or Chlormequat (CCC) but applications of Ethephon either pre- or post-harvest advanced ripening even in fruits treated at the 25% stage of development.

The work of Vendrell (1969, 1970a, 1970b) has clearly illustrated the importance of the method of applying growth regulators. The synthetic auxin 2,4-D when applied as a dip treatment hastened ripening by stimulating ethylene production but if slices were vacuum infiltrated ripening was delayed although ethylene production soon after cutting was stimulated. The differences in ripening response were shown to be related to the different pattern of distribution of 2,4-D obtained by the two methods; 2,4-D applied by dipping largely remained in the skin but that applied by vacuum infiltration was evenly distributed through the tissue. Opposite results were obtained with applications of gibberellic acid. Dipping of

whole fruits delayed the loss of chlorophyll and ripening but vacuum infiltration hastened ripening. Unpublished work at North Ryde showed that Alar and Chlormequat had little effect on ripening in banana fruit tissue whether applied by dipping or by vacuum infiltration.

Overall the results obtained by applying various growth regulators to fruits illustrate a wide diversity in responses in different species. The results emphasize particularly that each species has to be considered on its merits although some grouping on the basis of general similarities may be made, e.g., fruits which show a double sigmoid growth pattern, but even here the role of an individual regulator appears to vary considerably. A strong case can be made for concentrating work on a single species selected for its suitability for laboratory studies until the role and action of some of the major endogenous regulators have been resolved.

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Discussion

According to Dr McGlasson, the advancement of peach fruit maturity by application of Ethephon or Alar during early stage 2, is due to an increase in the rise of stage 3. In apricots 2,4,5T can be applied to advance maturity in early stage 2, but this effect is due to a shortening of stage 2 rather than an increase in the rate of stage 3.

The relationship between ABA concentration and ripening of grape berries is convincing, since the level in the skin, where sugars first accumulate, rises before the ABA level in the berry.

EFFECTS OF SUMMER APPLICATIONS OF ALAR ON FRUIT DROP AND ON KEEPING QUALITY OF APPLES

N. Veinbrants*

Introduction

Foliar sprays of the growth retardant succinic acid-2, 2-dimethyl hydrazide (Alar) causes many different physiological responses in apple trees. These responses vary with the time of application, the concentration, the variety and the vigour of the tree.

In addition to reducing the extension growth and stimulating flower bud development in apples (Batjer, Williams and Martin 1964; Edgerton and Hoffman 1965; Looney, Fisher and Parsons 1967; Luckwill and Child 1967; Veinbrants 1967, 1969 and 1972; Oldham and Greenhalgh 1968), Alar affects fruit set (Batjer, Williams and Martin 1964; Edgerton and Hoffman 1965; and Veinbrants 1969), reduces fruit size (Batjer, Williams and Martin 1964; Edgerton and Hoffman 1965; Fisher and Looney 1967; Martin, Lewis and Cerney 1968; Lord 1971 and Veinbrants 1969), increases fruit firmness (Williams, Batjer and Martin 1964; Edgerton and Blanpied 1965; Edgerton and Hoffman 1965; Fisher and Looney 1967; and Lord 1971), increases red colour (Edgerton and Hoffman 1966; Shutak, Kitchin and Dayawon 1966; and Luckwill and Child 1967), prevents fruit drop and lowers incidence of certain storage disorders (Batjer 1965; Edgerton and Blanpied 1965; Batjer and Williams 1966; Blanpied, Smock and Kollas 1967; Edgerton and Hoffman 1966; Edgerton, Forshey and Blanpied 1967; Fisher and Looney 1967; Forshey 1970; Lord, Southwick and Damos 1967; and Lord 1971).

Several authors (Batjer and Williams 1966); Fisher and Looney 1967; Forshey 1970) reported that Alar prevented fruit drop on apples when applied shortly after full bloom.

Experiments conducted with Alar in southern Victoria on several apple varieties indicate that early spring applications of Alar will not give sufficient drop control at harvest.

However, preliminary studies showed that summer applications of Alar reduced fruit drop in Gravenstein apples. During the last 3 years experiments were carried out in commercial orchards on Gravenstein, Jonathan, Delicious and Golden Delicious apples to evaluate the use of summer applications of Alar for the prevention of preharvest drop and study the effect on stored fruit (in air at 0°C). Results of these experiments are

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summarized in this paper.

Effect on Fruit Drop

Foliar sprays of Alar applied in summer at rates of 500, 750 and 1000 p.p.m. prevented fruit drop on Gravenstein, Jonathan and Delicious apples effectively and compared favourably with stop drop sprays (N.A.A. and 2,4,5-TP) now in commercial use. Timing of these conventional stop drop sprays is critical because of the relatively short period of effectiveness in preventing fruit drop. In addition either material usually tends to accelerate fruit ripening and cause some yellowing of ground colour of fruit if picking is delayed.

By contrast Alar controlled fruit drop effectively when applied between 83 and 43 days before harvest (withholding period for Alar is 42 days). This indicates that timing for Alar is not critical, which is a desirable feature for a stop drop spray.

Effect on Fruit Size

At harvest, fruit size was reduced significantly when Alar was applied 60 or more days before harvest on Jonathan and 76 or more days before harvest on Delicious apples. Later applications had little or no effect on fruit size at harvest.

Results indicate that the initial fruit size at the time of spraying has a greater influence on the reduction in fruit size at harvest than the rate of Alar used. In most cases the reduction in fruit size associated with Alar applications is undesirable under our conditions.

In these experiments fruit size was significantly reduced at harvest only when fruit circumference was 14.6 cm and less for Jonathan and 14.2 cm and less for Delicious when Alar sprays were applied. No significant reduction in fruit size occurred on Jonathans at harvest when fruit circumference was 15.1 cm or more in one experiment and 16.3 cm or more in another experiment when the Alar sprays were applied. Similar results occurred with Delicious apples.

It therefore appears that the reduction in fruit size normally associated with Alar is closely related to the size of the fruit at time of spraying. If fruit circumference is above 16 cm at time of application it seems likely that no reduction in fruit size will occur at harvest on Jonathan or Delicious apples. Thus fruit size would be a better parameter than the number of days before harvest for determination of the timing of Alar sprays. Further studies involving more frequent spray applications are necessary before this relationship can be accurately evaluated and adopted for commercial use.

Effect on Flesh Firmness and Fruit Storage Disorders

Nearly all Alar treatments significantly increased flesh firmness at harvest in Gravenstein, Jonathan and Delicious apples. This increase in flesh firmness in two Jonathan experiments was maintained during the 6½ months storage period and was still present in apples following the holding period of 7 days at 20°C. Alar at 1000 p.p.m. gave more consistent results than 500 p.p.m. on this measurement.

On Delicious apples the increase in flesh firmness obtained at harvest diminished during the storage period. Alar, at the concentrations used did not increase flesh firmness in Golden Delicious at harvest in this study.

No overall influence on incidence of storage disorders such as internal breakdown, superficial scald, deep scald or rots was observed due to the application of Alar on Jonathan, Delicious and Golden Delicious apples. Some Alar treatments reduced deep scald in one Jonathan experiment and superficial scald in Delicious apples.

Effect on Fruit Shape, Surface Red Colour and Fruit Maturity

Alar did not influence fruit shape (L/D ratio) or stem length of Gravenstein, Jonathan and Delicious apples in the year of spraying. However, small but significant reduction in stem length and L/D ratio was induced by some Alar treatments in Delicious apples in the year after spraying. It seems that if Alar is used in the concentration range from 500 p.p.m. to 1000 p.p.m. the effect on fruit shape in the following year will be negligible from a commercial viewpoint.

In several Jonathan experiments Alar increased the intensity of surface red colour but did not affect the extent of the red flush. At harvesting improved red surface colour was also observed visually on Alar and 2,4,5-TP treated Gravenstein apples. This was reflected in the higher percentage of fruit picked at the earlier picking dates. No red colour improvement was noticed in these experiments on Delicious apples.

The improvement in surface red colour due to Alar is not consistent and the factors involved need further investigation.

If flesh firmness and per cent soluble solids are used as parameters for fruit maturity then Alar seems to retard fruit maturity. No influence on ground colour or flavour of fruit was noticed on Alar treated trees during harvesting or detected after storage.

Effect on Extension Growth

Some Alar treatments reduced terminal shoot growth significantly when applied 83 days before harvest on

Jonathan apples and 76 or more days before harvest on Delicious apples. This indicates that extension growth by that time was not fully completed. Later applications of Alar had no effect on terminal growth.

In recent years the growth retardant Alar has been extensively investigated by research workers throughout the world because of its promising effect on tree growth and apple quality. The most consistent results with Alar have been observed in inhibiting extension growth, in promoting flower bud initiation and in preventing preharvest drop.

Alar sprays have frequently reduced fruit size and Martin, Lewis and Cerny (1968) reported this due to a decrease in cell number per fruit but not in cell volume.

Many authors (Batjer 1965; Batjer and Williams 1966; Blanpied, Smock and Kollas 1967; Edgerton and Hoffman 1965; Edgerton, Forshey and Blanpied 1967; Fisher and Looney 1967; Forshey 1970; Looney 1969; Lord, Southwick and Damos 1967; Lord 1971; McDonnell and Edgerton 1970; Sharples 1967; Williams, Batjer and Martin 1964) reported that Alar sprays have increased flesh firmness. Martin, Lewis and Cerny (1968) have noted an increase in Ca and decrease in N, and Williams, Batjer and Martin (1964) found more cellular material in Alar treated fruit, conditions which should result in increased firmness.

However this does not explain why apples treated with Alar in summer were also firmer at harvest.

Several authors (Batjer 1964; Blanpied, Smock and Kollas 1967; Edgerton and Blanpied 1965; Shutak, Kitchin and Dayawon 1966; Williams, Batjer and Martin 1964) found a significant reduction in storage scald of treated fruit, but others reported occasional cases of more scald (Edgerton, Hoffman and Forshey 1966) or no effect on storage scald (Lord, Southwick and Damos 1967). Batjer 1965; Batjer and Williams 1966; Lord, Southwick and Damos 1967; and Lord 1971 reported that Alar delayed the development of water core in Delicious. By contrast Edgerton and Blanpied 1965 found that appearance of water core was increased.

Reports have been published which indicate that Alar increased the incidence of core browning on Alar treated apples in air storage but not in C.A. (Edgerton, Forshey and Blanpied 1967; Blanpied, Smock and Kollas 1967; Sharples 1967 and 1971). Some authors (Looney 1969) found no influence on the incidence of storage disorders by Alar.

Several authors (Blanpied, Smock and Kollas 1967; Looney 1967; Sharples 1966 and 1971) found that Alar suppressed the rate of respiration of treated fruit during the climacteric period. A reduction in respiration rate in Alar treated fruit might account for improvements in storage and shelf life observed by many research workers. The results observed on the incidence on

storage disorders due to Alar is very conflicting.

For instance Alar reduces both water core and scald. These two disorders are frequently associated with opposite physiological conditions, i.e., storage scald with immaturity and water core from advanced maturity.

The tendency toward more colour and less scald in storage suggested a slight hastening of maturity by Alar sprays. Conversely reduced fruit size, delayed fruit drop, delayed climacteric, lower rate of ethylene evolution, lower ethanol content, increased flesh firmness and incidence of brown core reported by many authors suggested a slight delay in maturity.

These conflicting results with Alar may be due to differences in response of variety, season or geographical location and the specific effects of the material. The results also emphasize in the experiments with Alar the need for the examination of many fruit characteristics over several seasons in the evaluation of the effect of orchard treatments on the maturity and senescence of apple fruits. In addition a better understanding in the mode of action by Alar will greatly help to evaluate and explain the results.

Summary

Results of these studies indicate that summer applications of the growth retardant Alar are highly effective in reducing fruit drop on Gravenstein, Jonathan and Delicious apples. In addition Alar increased flesh firmness of fruit at harvest and this frequently persisted during conventional cold storage. However, this tendency of Alar to inhibit the rate of flesh softening is much more marked at harvest than after 6½ months in storage.

Limited experience in conventional storage with Jonathan, Delicious and Golden Delicious apples indicates that Alar does not adversely affect storage life of treated fruit. By contrast, due to increased flesh firmness, Alar helps to prolong shelf life and improve the appearance and quality of apples after storage.

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Discussion

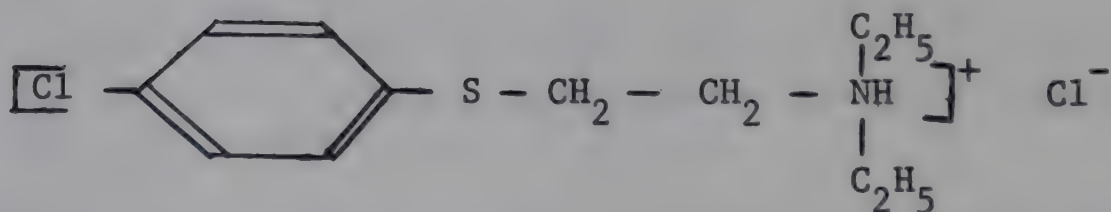
It is difficult to decide whether one should sample fruit sprayed with Alar in the summer, at random or according to fruit size. It is clear, since sprays are applied after the cessation of cell division, that any effects on fruit size will be due to an effect on cell size. Therefore, if sprayed and unsprayed fruit are sampled according to size at harvest the sprayed fruit will contain a higher number of cells than unsprayed trees.

COLOUR DEVELOPMENT IN TOMATOES

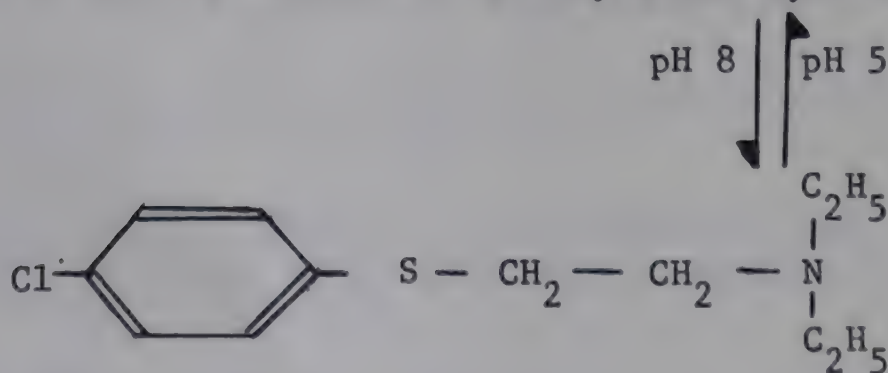
T.H. Lee and M.R. Baqar*

Many aspects of fruit production are now being controlled by the judicious use of chemicals or are currently receiving attention so that greater control over the particular process may be exercised (Looney 1972). For instance, control may be obtained over the number of fruit set, the maturation time of the fruit, pre-harvest drop and even the shape of the fruit with applied chemicals or as they are more commonly referred to, growth regulators.

The control of fruit colour, an important quality characteristic for both the fresh market and for processing, has been almost neglected except in the context of chemicals such as Alar and Ethephon, which can accelerate or delay the onset of fruit ripening. Recently, however, chemicals have been synthesized which can have a profound effect on the colour of fruit, especially those fruits which contain carotenoid pigments. Such a chemical is 2-(4-chlorophenylthio) triethylamine hydrochloride (CPTA).



2-(4-chlorophenylthio) triethylamine hydrochloride



2-(4-chlorophenylthio) triethylamine

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This chemical came to light during a programme conducted by Dr Coggins at the University of California, Riverside, to find means of intensifying citrus fruit colour, especially the peel colour of oranges. Apparently climatic conditions in some citrus growing areas of the United States, i.e., Florida, are such that the peel of oranges frequently does not attain a satisfactory orange colour. It has been established that cool nights and clear sunny days are required for the development of satisfactory peel colour. The Florida citrus industry resorts to a coal tar dye, citrus yellow, to colour up orange peel but as this dye was soon to be outlawed, the industry began searching for new ways to colour oranges.

CPTA had been found to cause albinism in leaves (Cooke, pers. comm.) and when sprayed on citrus fruit caused an intensification of peel colour (Coggins, Henning and Yokoyama 1970). The intensified colour was due to lycopene synthesis in the fruit peel and it was possible to produce oranges with a peel colour ranging from a desirable intense orange colour to blood red colour. These workers at Riverside and ourselves investigated the action of CPTA in a variety of carotenogenic systems such as moulds, bacteria and other fruit species and found a similar synthesis of lycopene, usually in impressive amounts. Tables 1 and 2 show the pigment analyses for CPTA-treated *Phycomyces blakesleeianus* and Navel orange flavedo.

TABLE 1

Carotenoid Distribution in the Mould *Phycomyces blakesleeianus*
Treated with 25 p.p.m. CPTA (Lee *et al.* - unpublished results)

Polyene	$\mu\text{g} / \text{g dry wt}$	
	Control	treated
Phytoene)	65	85
Phytofluene)	11	35
ζ -carotene) Acyclic	16	21
Neurosporene) Carotenes	6	4
Lycopene)	2	102
γ -carotene	-	58
β -carotene	393	361
Total	498	666

TABLE 2

CPTA (5000 p.p.m.) Effect on Carotenoid Content of Flavedo of Navel Orange (Yokoyama et al. 1972).

	µg / g dry wt			
	Control	CPTA treated		
		Immature	Green	Fully matured
Phytoene	37.2	78.8		82.1
Phytofluene	22.6	24.1		26.2
ξ-carotene	25.4	70.1		68.2
Neurosporene	-	41.2		42.3
Lycopene	-	264		240
γ-carotene	-	22.3		17.8
β-carotene	0.6	trace		trace
Carotenols including epoxides	284	20.1		339

When the carotenoid patterns of these systems are analysed it is found that along with the increase in lycopene product and lycopene production occurs in systems which produce little or no lycopene naturally, there is a decline in the relative amount of β-carotene and/or oxygenated derivatives of β-carotene synthesized and an increase in the relative amount of the acyclic carotenes which are considered precursors of lycopene (Tables 1 and 2). It appears that, besides stimulating carotene synthesis at some point before the formation of the C40 structure, CPTA prevents the cyclization of the acyclic carotenes to form cyclic carotenes such as β-carotene. As little is known about the control mechanisms operating at the C40 level in carotenoid biosynthesis, CPTA offers a possible breakthrough for the investigation of these mechanisms.

Now, we thought that since CPTA promotes the synthesis of lycopene in a variety of carotenogenic systems it may have some value in increasing the colour of tomato fruit in which the dominant pigment is lycopene, accounting for some 90% of the total pigment content. We envisaged that CPTA could be used in two situations, (a) as a pre-harvest spray probably in conjunction with Ethephon which has been shown to accelerate and concentrate tomato fruit ripening but has no effect on intensifying colour and (b) as a post-harvest dip at a central sorting operation where green or semi-ripe fruit are eliminated.

We have begun a series of experiments with tomato fruit grown in the glasshouse and also in the field. In the glasshouse we have dipped or injected individual fruits of the Roma 886

erty with CPTA in the hydrochloride form at concentrations up to 5000 p.p.m. Table 3 shows the total pigment content of fruit dipped in CPTA at the 75% stage of development (where this equals the time from anthesis to first red colour in the fruit) and picked at varying intervals after treatment. At all times the CPTA - treated fruit have a higher pigment content than the control fruit, the increase being of the order of 50%. Similar results were obtained with fruit treated at the 50% stage of development.

TABLE 3

CPTA effect on total pigment content ($\mu\text{g/g}$ fr wt) expressed as lycopene of tomatoes, cv. Roma 886, treated at the 75% stage of development and analysed at intervals after treatment.

Time after treatment	Control	CPTA	
		1000 p.p.m.	5000 p.p.m.
0	5	5	5
5	8	9	12
10	34	48	62
13	46	60	74
17	83	91	119

We have routinely checked other indices of tomato fruit quality in our work, such as soluble solids, pH, total acidity and ascorbic acid. Table 4 indicates that the ascorbic acid contents of CPTA-treated fruit are generally higher than the control fruit. The values are for fruits treated at the 50% stage of development and similar results were found for fruits treated at the 75% stage of development. These are very preliminary results and we are using the indophenol method for ascorbic acid determination, which measures total reducing substances. We are checking the results with a method which is specific for ascorbic acid and also with further experiments.

TABLE 4

CPTA effect on ascorbic acid content ($\text{mg}/100 \text{ g}$ fr wt) of tomatoes, cv. Roma 886, treated at the 50% stage of development.

Days after treatment	Control	CPTA	
		1000 p.p.m.	5000 p.p.m.
0	-	-	-
5	1.1	1.6	1.8
30	4.7	6.0	6.2

Our lone field trial last summer at Hawkesbury Agricultural College was a wet failure - shortly after spraying the plots with CPTA, Ethephon and combined treatments of CPTA and Ethephon, the crop was hit with 3 inches of rain in an hour, which waterlogged the plants. Before the rain intervened, we did observe that these chemicals at the concentrations used, 1000 and 5000 p.p.m. CPTA and 500 p.p.m. Ethephon, caused varying amounts of leaf burn and defoliation. While this may not be serious a day before harvest, earlier defoliation will lead to sunburn of the unprotected fruits. We are currently studying the effects of CPTA and some other plant growth regulators such as Cycocel on chloroplast development in a pumpkin cotyledon system. The pumpkin seeds are germinated for 4 days in the dark at which time the cotyledons are excised and floated in solutions of the various growth regulators, generally in the light. Chloroplast development in the expanding cotyledons which form the first photosynthetic leaf of the plant may be followed by chemical means (i.e., chlorophyll estimation) or with the electron microscope. We have been able to establish that CPTA is a strong inhibitor of chloroplast development at low concentrations.

CPTA is equally effective when applied to tomato fruit post-harvest. In one experiment mature green tomatoes, cv. Grosse Lisse, were dipped in CPTA, Ethephon, and combinations of the two chemicals and then stored at 20°C until fully ripe. The pigment patterns of these fruit have been analysed and Table 5 shows the lycopene content after 7 and 12 days storage at 20°C and 30°C, respectively, following treatment. The CPTA-treated fruit stored at 20°C accumulate lycopene much more rapidly than control or Ethephon-treated fruit and further analyses indicate that the pigment content of fully ripe CPTA-treated fruit is substantially greater than the ripe control fruit. Moreover, CPTA appears to be able to partially reverse the high temperature inhibition of lycopene synthesis in tomatoes.

TABLE 5

Effects of CPTA and Ethephon on the Lycopene Content
($\mu\text{g/g}$ fr wt) of Mature Green Tomatoes Stored at 20°C
for 7 and 12 days respectively.

Treatment	Lycopene content	
	20°C	30°C
Control	17.0	0.5
Ethephon 500 p.p.m.	25.5	1.5
CPTA 5000 p.p.m.	164.3	12.5

The results reported in this paper are of a preliminary nature and we hope to substantially build upon them during this summer. Despite their preliminary nature I think you will agree that chemical alteration of fruit colour is a future possibility.

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Discussion

Since the amine form of CPTA is effective at 100 p.p.m. while the HCl form requires 5000 p.p.m. because it is not readily taken up, the problems associated with residue accumulation might be reduced or avoided by using the amine form.

Regreened Valencia oranges treated with CPTA became pink after 16 days. This problem could be avoided if the fruit is marketed after the chlorophyll has disappeared and some lycopene has been synthesized but before there has been sufficient synthesis to give a pink or red colouration.

CPTA stimulation of lycopene synthesis is better in the presence of Ethephon because enzyme levels are higher in mature fruit; however CPTA does not appear to affect maturity itself.

PHYSIOLOGY OF APPLE FRUITS AT LOW TEMPERATURES

W.B. McGlasson and J.K. Raison*

Chilling injury has been defined as a physiological disorder which occurs in plants when they are exposed to temperatures below about 10°C but above their freezing points. The severity of injury generally increases as temperature decreases within the chilling range and as the duration of exposure increases. Traditionally, fruits of tropical and subtropical origin, e.g., banana and sweet potato are considered chilling sensitive, with a critical temperature in the range 10-12°C. However, low temperature disorders are also found in a range of plant tissues of temperate origin, e.g., citrus, peaches and some varieties of apples. In these species the critical temperature is about 5°C. Determination of critical temperatures on the basis of physiological responses can only be approximate because symptoms of injury may vary and their expression may be masked or delayed by such factors as high humidity and the maintenance of a low level of fungal infection.

Lyons, Wheaton and Pratt (1964) reported that the membranes of mitochondria isolated from chilling resistant plants, e.g., cauliflower, were more flexible than those of mitochondria isolated from chilling sensitive plants, e.g., sweet potato. They also showed that mitochondria from chilling resistant plants tended to contain more unsaturated lipids than sensitive ones. Recently Lyons and Raison (1970) have significantly advanced our understanding of chilling sensitivity by showing that at chilling temperatures there is a significant increase in the Q₁₀ of the oxidation of a respiratory substrate (succinate) by mitochondria from chilling sensitive species, but no change in the Q₁₀ for mitochondria from resistant species. The breaks or transitions in the Arrhenius plots of the data for chilling sensitive species occurred in the range 9-12°C. Further work by Raison *et al.* (1971) using electron spin resonance (E.S.R.) measurements have shown that the temperature induced transition is associated with lipid regions of the mitochondria membranes.

We have now applied these same techniques to mitochondria from six apple cultivars which vary in susceptibility to low temperature breakdown (L.T.B.).

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TABLE 1

Transition temperature range determined by E.S.R. measurements and Arrhenius energies of activation (Ea) calculated from the rates of succinate oxidation above and below the transition temperature for mitochondria from 6 cultivars

Cultivar ¹	Transition temperatures range from E.S.R.data C	Ea above transition temperature range kcal/mole	Ea below transition temperature range kcal/mole
Jonathan, Bathurst, N.S.W.	3 - 5	10	20
Jonathan, Scoresby, Vic.	4 - 6	10	22
Jonathan, Lenswood, S.A.	9 -10	7	21
Coxs Orange Pippin, Tas.	8 -10	9	30
Red Delicious (Richared), Orange, N.S.W.	4 - 5	12	21
Granny Smith, Bathurst, N.S.W.	6 - 8	9	29
Golden Delicious, Orange, N.S.W.	6 - 8	11	18
Democrat, Bathurst, N.S.W.	3 - 6	9	23

1. Jonathan and Coxs Orange Pippin are considered susceptible to L.T.B. (Carne 1948); Red Delicious, Granny Smith, Democrat and Golden Delicious have low susceptibility (Carne 1948, Lutz and Hardenburg 1968).

Table 1 shows that mitochondria from all the cultivars exhibited a temperature induced phase transition. The results are for single lots of fruit in the 1971-2 season. We are unable to explain either the relatively wide range of values shown or the lack of a pattern which can be related to susceptibility to L.T.B. Another puzzling feature of this work was the failure of deoxycholate and of a non-ionic detergent to eliminate the transition in succinate oxidation. In all previous studies with mitochondria from chilling sensitive plants these compounds abolished the transition (Raison, Lyons and Thomson 1971).

Raison (1972) has suggested that a large increase in the Q_{10} of mitochondrial activity at low temperatures could lead to an accumulation of intermediates arising from glycolysis. The rationale behind this suggestion is that none of the enzymes of glycolysis are associated with or bound to membranes and would be expected to exhibit a constant Q_{10} over the range of chilling to non-chilling temperatures. This suggestion is supported by the work of Wills, Scott and McGlasson (1970) who showed that acetic acid accumulates to high levels in Jonathan early in storage at 0°C but later falls to low levels before the appearance of visible symptoms of L.T.B. Wills and McGlasson (1971) showed that the accumulation of acetic acid was much reduced if the storage temperature was raised to 5°C or higher. However, the reduced accumulation of acetic acid at higher temperatures could have been partly explained by the increased evolution of butyl acetate, a major component of the volatiles given off by apples (Wills and McGlasson 1971).

If the accumulation of acetic acid is at least partly due to an increase in the Q_{10} of mitochondrial activity at low temperatures then a similar accumulation of acetic acid should be observed in all of the cultivars listed in Table 1. At present we have no comparative data for these cultivars. Even with this lack of information it is possible to speculate about the significance of these temperature effects in apples in relation to the susceptibility of the different cultivars to L.T.B. Assuming that in all apple cultivars stored at 0°C there is a strong tendency to accumulate respiratory intermediates such as acetic acid, then the difference in susceptibility to L.T.B. between cultivars may be explained by differences in their capacity to metabolize acetic acid by alternate pathways. There is strong evidence that one such pathway in apples involves the biogenesis of isoprenoid compounds (Wills and Patterson 1971; Wills and Scott 1971). Comparative studies on the metabolism of isoprenoid compounds in cultivars of high and low susceptibility to L.T.B. may be productive.

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Discussion

The data in the table are based on individual fruit without regard to the physiological age. Further investigations may show that maturity, which is linked with L.T.B., is also linked with transition temperatures and may explain the high variability.

The fate of acetate in the tissues is now of great interest. Rising temperatures cause a reduced accumulation of acetate in fruit and a greater loss of the acetate, mainly in the form of a volatile compound (butyl-acetate). Disruption in the metabolism of the fruit occurs when the accumulation is greater than the loss. However, acetate is no longer present when

breakdown in the fruit occurs. The best working hypothesis at the moment is that acetate is possibly metabolized into the isoprenoid compounds.

POST-HARVEST PHYSIOLOGY OF CHINESE GOOSEBERRIES

M.S. Reid and H.K. Pratt*

Introduction

The Chinese gooseberry, or Kiwi fruit (*Actinidia chinensis*) is becoming a crop of some significance to New Zealand's total production of horticultural crops. Last season, for example, production of this fruit was 3,000 tons, of which 1,160 tons were exported as fresh fruit, realizing export earnings of over \$2,000,000. At present, the picking and marketing operation is a very seasonal one, the crop being so small that the limited facilities available can cope for the month or so that the harvest spans. Essentially all fruit that attains export grade quality are shipped as soon as practicable so that there are few problems with prolonged storage at present. W.A. Fletcher has extrapolated from the logarithmic increase in plantings of Chinese gooseberries that the production by 1980 will be 8,000 tons. In order to have some information about the crop before production reaches these larger quantities, we have been carrying out an active research programme into the chemistry, physiology, biochemistry and processing of this fruit. In this paper we will report results from one season's extensive physiological studies, and discuss the implication of the results in the practical handling of the fruit.

Materials and Methods

Actinidia fruits (variety Bruno) were harvested randomly from four vines on the DSIR property at Oratia. The blossom period is very short (about 1 week), and no significant differences were found, in any of the quantities measured, between fruits tagged at different times during the blossom period. For most experiments, fruits were picked at 14-day intervals. Samples for chemical analysis were immediately analysed, or blast frozen (-30°F) pending analysis. Samples for measurement of respiration and ethylene production were placed individually in jars, ventilated with a constant air flow (ca. 1 litre/hr), in a constant temperature room (20°C).

Measurement of CO_2 and ethylene production by the fruits was by standard procedures - the ethylene detection system was capable of measuring down to 1 part in 1×10^9 in a 1 ml air sample. Texture measurements were made with an Allo-Kramer Shear Press fitted with a 100 lb ring. Other chemical analyses were by standard procedures.

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Results

Growth

Tagged fruits spread over the four sample vines and measured at weekly intervals showed an unusual growth pattern for fruits. The volume of the fruits, based on an assumed regular shape (cylinder plus sphere) increased in a triple sigmoid fashion. This growth pattern was highly significant statistically, and has been found in growth data recorded from previous seasons.

Respiration and Response to Ethylene

The basal respiration of the fruit showed a typical pattern, with the high respiration of very immature fruit reducing with maturity to a low level. When treated with ethylene gas, the immature fruit responded with a rapid burst of respiration. This response decreased as the fruit became more mature until fully mature fruit did not show any respiratory response at all, except for a slower rise accompanying final fermentation of the fruit.

Chemical Changes During Maturation

The levels of soluble solids, acids, sugars, starch and pectins followed patterns typical for many maturing fruit, reaching a 'ripe fruit' state about 35 weeks after anthesis, at the time when the respiratory response to ethylene drops to nil. The soluble solids change in a very predictable fashion, suggesting that this quantity may be a useful guide to fruit maturity.

Natural Ripening

With many fruits that have been studied the time of ripening is a predictable one, normally stated in days from anthesis. This is not so for Chinese gooseberries, where the ripening of individual fruits harvested at the same time may be separated by as much as 25 weeks. Accepting such variation for individual fruit, there is also a relationship (for mature fruit) between the time of harvest and the date of ripening. The mean ripening date at 20° for mature fruit was about 5 weeks after harvest. The natural ripening is attended by a massive production of ethylene as in climacteric fruits, but the respiratory response observed in immature harvested fruit is not observed in any fruit ripening naturally. There is a slow rise in respiration attending final fermentation and decomposition of the fruit. Immature fruit which do not ripen naturally can be triggered to ripen with ethylene after many weeks, but the natural loss of ethylene response appears to occur in the jar as well as on the vine, and there is only a weak respiratory rise.

Effects of Ethylene Treatment

Immature fruits treated with ethylene show a rapid respiratory response to the hormone. This is accompanied by an acceleration of ripening, as evidenced by softening of the fruit, hydrolysis of starch and accumulation of sugar, changes in the pectin components of the fruit, and appearance of aroma. Treatment with ethylene stimulates the fruit to produce high levels of ethylene itself once the gas is removed.

Discussion

The Chinese gooseberry is the only known fruit to have a triple sigmoid growth curve. It is not certain whether the Chinese gooseberry has a true climacteric although hydrolysis of starches to sugars takes place. Ethylene brings about uniform ripening of mixed maturity fruit and a similar procedure to that used for bananas is recommended to retailers. Chinese gooseberries can be stored up to 9 months at 0°C. The presence of ethylene at this low temperature has not been known to initiate ripening although it could be an advantage to remove it. Fruit remaining on the vine will not drop off and if left long enough will be eaten by birds.

Care is needed with transport in ships with mixed cargoes such as apples which give off a lot of ethylene and it has been found necessary to place scrubbers in ship's holds. At present only two companies in New York and Vancouver use ethylene to ripen imported Kiwi fruit. Strong recommendations are going to be made for this practice to become universal.

Desirable Eating Qualities of a Chinese Gooseberry

- 1) Soft to touch
- 2) Internally translucent
- 3) Aromatic
- 4) Not reached the fermented stage

POST-HARVEST PHYSIOLOGY OF TAMARILLOS

M.S. Reid* and H.K. Pratt**

Introduction

The tamarillo, or tree tomato (*Cyphomandra betacea*), while not as important a subtropical fruit as the Chinese gooseberry in New Zealand, is nevertheless grown in quite substantial quantities. Last year, for example, 1,100 tons of fruit was grown, and a substantial quantity (100 tons worth \$15,000) was exported. In this report we will describe the physiology of this fruit, which appears to be a typical non-climacteric fruit.

Materials and Methods

The tree tomato sets fruit over an extended period, and fruits of known age were obtained by tagging fruit which had just set (flower parts withered and fruit commencing expansion) at weekly intervals. Both yellow and red cultivars were tagged, and all trees were grown in a local orchard. For comparison of fruit it proved more convenient to make samples by harvesting at one time fruit set at different dates, thereby obtaining a comparison at one point in the season of fruit of different ages. Methods for measuring respiration and ethylene production were as described previously. (See "Post-harvest physiology of Chinese gooseberry", p.193.)

ResultsGrowth

Tamarillos set fruit over a very extended period (more than 20 weeks), so that all stages of the fruit's maturation could conveniently be examined at once. Growth as measured by any of the usual parameters was rapid and linear to a final mature size about 15 weeks after anthesis. This is well before the fruit becomes eating ripe on the tree (22-25 weeks).

Respiration and Ethylene Production

The tamarillo is a member of the Solanaceae, and shows rapid changes in external appearance during the last few weeks of its maturation on the tree which would suggest a climacteric fruit such as the tomato - a change from greenish purple to a deep red, development of sweetness and loss of acid, and final

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abscission from the tree. Sample fruits of all maturities were placed individually in respiration jars to examine their respiration and ethylene production. Respiration decreased to a low level with increased maturity, and there was a slightly higher respiration rate in fully mature fruit, but no ethylene production could be detected in any fruits except immediately after harvest (probably a handling effect). A respiration rise, and production of ethylene did occur in all fruit when decay organisms (which are sub-epidermal and latent in this fruit) started aggressive infection.

Response to Ethylene

Treatment with ethylene increased the respiration rate of fruits of all ages, but the age of the fruit at harvest influenced the pattern of response, with a dramatic response in young fruits and a very small response for mature fruits. Fruit treated with ethylene softened and developed yellow flesh colour - ripening as much as would be expected from their maturity at harvest. The most mature fruit developed a full ripe flavour, but the ethylene treatment enhanced the onset of the latent *Glomerella* infections which are a serious post-harvest problem in this fruit.

Effect of Heat Treatment

It has been shown that a mild heat treatment of harvested fruit (50°C for 10 min.) markedly improves storage life by killing subepidermal latent fungal inocula. This treatment has the disadvantage that it results in shrivelling of the calyx, and loss of the surface waxes. Fruit that has received this treatment has been rejected by inspectors as being too forward. Examination of the respiration of treated fruit showed that the heat treatment resulted only in a temporary burst of respiration, which quickly subsided to the control level, indicating that heat treatment has little physiological effect on the fruit.

Discussion

Tamarillos are susceptible to a range of fungi which are difficult to control and are thought to be systemic. Heat treatment will extend the storage life from 2 weeks to about 12 weeks. Use of systemic fungicides has not been successful. They are susceptible to a wide range of viruses and remain relatively virus free for only about 2 years. The viruses are not seed transmitted but infection is from neighbouring plants. Although plants can live for 8 or 9 years they are only used commercially for about 4 years.

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Storage should be at 5°C as tamarillos suffer chilling injury at lower temperatures. All exports are as fresh fruits to Australia and U.S.A.

UNEVEN RIPENING IN APRICOTS

M.S. Reid and G. Strachan*

Introduction

In some varieties of apricot unevenness in the onset of ripening results in a condition known locally as 'green shoulders' where the stem end of the fruit may be hard and unripe while the blossom end is fully ripened. This is a serious problem with the Moorpark variety which is extensively grown in Central Otago, causing fresh market fruit to be very variable, and canning fruit to be picked sufficiently immature to ensure minimum loss to the processor.

During a study of the changes during development and maturation of apricots, it was shown that ethylene treatment markedly accelerated the ripening of the fruit. This paper reports a study of ethylene treatments carried out in an attempt to eliminate uneven ripeness in canned apricots.

Materials and Methods

Moorpark apricots of uniform size and maturity were harvested at intervals during maturation from trees at the DSIR research orchard in Earnscleugh, Central Otago, and flown in moist insulated packaging to Auckland within 12 hours of harvest for physiological studies, or chemical analysis. Larger samples of fruit were purchased in case lots from commercial growers and air-freighted to Auckland. Measurement of surface colour was made with a Beckman DU spectrophotometer equipped with a reflectance attachment, and fruit texture was measured with a shear press on a standard sized fruit piece. For analysis of uneven maturity, a cork boring was made from two diagonal cheeks of the fruit, with the suture held vertically so that one plug of stem end tissue, and one plug of blossom end tissue, was obtained from each fruit. Spectral reflectance of the skin and texture of the flesh were then analysed for each piece.

Other analyses of physiology and chemical constituents were carried out by standard methods. Fruit was canned using highly standardized fills, exhausting, syrup concentration and cooks. Such ~~factors~~ as drained weight and syrup 'cut out' were measured after 2 months to allow equalization. Colour of the canned product was measured with a Biospec. Taste panels evaluated pureed drained fruit for colour and flavour.

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Results

Changes During Maturation and Ripening of Apricots

The pattern of respiration and ethylene production during maturation of apricots resembles those reported for other stone fruits, with increased respiration and ethylene production accompanying the final ripening phase. Analysis of sugar and acid changes demonstrates that the apricot is a fruit in which the final few weeks on the tree are of paramount importance, with rapid increases in the levels of sugar, and a decline in acid. Imported sugar supplies all the sugar in the ripened fruit, since there is very little starch as reserve carbohydrate. During this final period, too, there is a rapid increase in weight of the fruit up to full ripening.

Effect of Ethylene on Immature Apricots

The effect of ethylene gas on the respiration of apricots was determined using fruits of different maturities. Apricots respond to ethylene treatment with a burst of respiration, accompanied by loss of chlorophyll, softening, and accumulation of carotene. Examination of the evenness of ripening in bulk samples of fruit treated for different times with ethylene suggested that ethylene treatment pushed forward the maturity of both the blossom and stem end of the fruit, but resulted in a more even ripeness. The effect was most pronounced in a three-day treatment with ethylene at 20°C - fruit of advanced maturity did not respond as well as 'canning ripe' fruit.

Effect of Ethylene on Canned Apricot Quality

Measurement of the texture, colour, and taste-panel acceptability of apricots canned after various lengths of ethylene treatment suggested that this procedure might well improve the quality of the commercially canned product. Since the major change in the final phase of tree maturation is accumulation of sucrose, fruit for canning might advantageously be harvested somewhat immature to gain maximum benefit from the ethylene treatment.

Ethaphon as an On-tree Treatment

Treatment of apricots on the tree with Ethaphon (Chlorethane phosphonic acid) as an alternative to post-harvest ethylene treatment was not satisfactory. The hormone causes 'gummosis' of the trees, and does not appear to have as marked an effect on evening the maturity of the fruit.

Discussion

A one- to two-day treatment with ethylene removed the green shoulders from the fruit and produced more uniform ripening which in turn gave the apricot a good colour and a sweet desirable taste. A long ethylene treatment could induce breakdown of canned fruit.

Ninety per cent of canning apricots in New Zealand are of Moorpark variety, mainly because it is not susceptible to 'blast' disease.

POST-HARVEST FUNGICIDES

B.L. Tugwell*

Introduction

Fresh fruits and vegetables are subject to attack by pathogenic fungi during all stages of handling from harvest until eventual consumption. Post-harvest deterioration can be reduced by refrigerated transport and storage, but some fruit and vegetable are injured by storage at temperatures low enough to inhibit growth of pathogenic fungi. Additional protection is required to ensure that the fresh commodity will not be spoiled when held at ambient temperature for several days in the retail market.

Post-harvest treatment is aimed at reducing the number of individual fruits which will become unmarketable due to microbial spoilage. With the increasing use of consumer pre-packaging complete control of pathogenic organisms is required to prevent spoilage of the package unit.

Post-harvest diseases arise as a result of infection in the field before harvest and infection of injuries resulting from picking and handling operations. Diseases in the first category develop from spores embedded in the host tissue during the growing season. Further development may be delayed until a certain stage of physiological maturity. Control of pre-harvest infections by post-harvest treatments is often not as successful as with post-harvest infections. The aim of post-harvest treatment is then to prevent further spread of the disease to surrounding fruits.

Physical treatments have been evaluated in recent years as potential 'residue free' methods for controlling post-harvest diseases. Heat and radiation treatments, however, lack the biological specificity to eradicate the parasite without damaging the host.

In recent years fungicides which are extremely selective against pathogenic organisms and of negligible toxicity to the host, have been made available for post-harvest treatment of fruit and vegetables.

The range of chemical treatments available was reviewed at the 1968 Fruit and Vegetable Storage Research Conference. Since then several new fungicides have replaced less efficient treatments and new application methods have been devised to take advantage of unique biological properties of these materials.

The effectiveness of a post-harvest fungicide depends on the depth of inoculation, growth rate of the pathogen, susceptibility of the host to infection, temperature, humidity, and the depth to which inhibitory concentrations of the fungicide may

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penetrate into the host tissues. Prompt application of the recommended post-harvest fungicide is the key to successful control of the pathogen.

Research has provided a wide range of post-harvest techniques which can be utilized (in association with effective fungicides) to reduce deterioration of fruit and vegetables during storage and marketing. In this review the most effective and practical post-harvest fungicides will be considered in relation to the specific requirements of each fruit and vegetable.

Important Post-harvest Diseases and Fungicide Treatments

The following Table lists the most important post-harvest diseases affecting Australian fruit and vegetables and the range of fungicides available for their control. The Table illustrates the increasing importance of the benzimidazole group of penetrant fungicides for controlling post-harvest diseases.

TABLE -Fungicides for Controlling Post-harvest Diseases

Fruit or vegetable	Major diseases	Recommended fungicide	Superseded fungicide	Promising alternatives
Citrus fruits	<i>Penicillium</i> moulds Stem end rots	Thiabendazole, benomyl or 2,4-D	S.O.P.P.	BAS 3460F Topsin M
Pome fruits	<i>Penicillium</i> moulds <i>Gloeosporium</i>	Thiabendazole or benomyl	S.O.P.P. Captan	BAS 3460F Topsin M
Bananas	<i>Nigrospora musae</i> <i>Gloeosporium musarum</i>	Thiabendazole or benomyl	Salicy-lanilide	BAS 3460F Topsin M
Stone fruits	Brown rot <i>Rhizopus</i> rot	Benomyl or thiabendazole dichloran	S.O.P.P.	BAS 3460F Topsin M
Grapes	<i>Botrytis</i> rot	Sulphur dioxide	-	-
Vegetables	Bacterial soft rot	Hypochlorite	-	-

Post-harvest Fungicides for Citrus

Green mould (*Penicillium digitatum*) and blue mould (*Penicillium italicum*) are two of the most important post-harvest diseases of citrus in Australia. From 1954 until 1969 commercial control was achieved by the application of S.O.P.P.

as a two-minute, 2%, dip rinse treatment (Long and Roberts 1954) followed by S.O.P.P. in wax (Leggo and Seberry 1962).

Since S.O.P.P. is not effective on ungerminated spores (Christ 1965) diphenyl, a volatile chemical, was impregnated into pads or fruit wrappers to prevent sporulation of the fungus and the contamination of surrounding fruit. Provided recommended procedures were followed S.O.P.P. provided good wastage control but there was a high risk of rind injury if the chemical was not used correctly. Close control of pH temperature, concentration and dipping time were necessary to ensure adequate fungicidal treatment and freedom from rind injury. Oleocellosis injuries caused by harvesting and handling turgid fruit were coloured brown after a two-minute dip in S.O.P.P. Development of unsightly blemishes several days after packing the fruit resulted in rejection of large quantities of export fruit. These factors, together with a threatened shortage of S.O.P.P. in 1969 led to the rapid acceptance of thiabendazole (T.B.Z.) as a post-harvest treatment for citrus when approval was given to treat export fruit in 1970.

Application of Benzimidazole Fungicides to Citrus

The effectiveness of T.B.Z. was demonstrated by Crivelli (1967) and in Australia by Seberry and Baldwin (1968). Benomyl and more recently N.F. 44 (methyl thiophanate) and BAS 3460F (benzimidazole carbamic acid methyl ester) have all been shown to provide effective control of blue and green mould. All of the benzimidazole fungicides are formulated as non phytotoxic wettable powders which can be left as a residue on the surface of the fruit. Initially T.B.Z. was applied as a replacement for S.O.P.P. as a two-minute dip in the wash tank. Rapid settling and stripping of the powder from solution, bacterial contamination of dip tanks, and high application costs were the main problems of commercial application (Seberry 1969). In order to obtain efficient and effective application of wettable powder formulations a flood application system was developed for incorporation into citrus packing lines (Murray Citrus Sub Committee 1971). A 30-second flood application of 1,000 p.p.m. T.B.Z. at the rate of 2-3 gallons per bushel is recommended. The T.B.Z. is applied after washing and prior to waxing so as to minimize the chance of reinoculation after treatment. A system for maintaining the concentration of the fungicide using an agitated header tank containing double the recommended concentration of T.B.Z. (Tugwell *et al.* 1970) and a simple method for determining the concentration of T.B.Z. (Glennie-Holmes 1972) ensure effective treatment of fruit processed for export in South Australia. Provided the recommended treatment is

applied no additional protection against blue and green mould is required. Several attempts have been made to incorporate T.B.Z. into wax (Wicks and Volle 1972; Cuille and Bur-Revault 1969; Gutter 1969; Wild 1972), but in all reports reduced control of wastage occurred. Waxing of fungicide particles and poor wax coverage are the reasons given for reduced effectiveness.

Prompt treatment after harvest is essential if effective wastage control is to be achieved. If delays occur in the packing shed or fruit is degreened with ethylene a 500-1,000 p.p.m. dip in 1,000 p.p.m. T.B.Z. immediately on receipt at the packing shed is justified (Rippon 1972). This treatment is an effective alternative to ammonia gas (Leggo and Seberry 1964) and 2-amino butane (Grierson 1968) for mould control in degreening rooms.

Stem end rot caused by the melanose fungus *Diaporthe citri*, a problem of coastal grown citrus is effectively controlled by T.B.Z. and benomyl (Seberry 1968), but a treatment of 500 p.p.m. 2-4D in wax for stored lemons is recommended (Wild 1972). A stem end rot not controlled by the benzimidazole fungicides, *Alternaria*, has been found in late harvested and cool stored fruit. 2-4D and G.A. have been suggested for preventing infection by reducing the rate of senescence of the stem end of the fruit.

Future Developments

Most of the problems associated with the application of wettable powder fungicides to citrus have been solved. Existing equipment recommended for application of thiabendazole is suitable for the application of the range of effective fungicides now available if and when approval for post-harvest application is obtained.

Benomyl

The recent approval of benomyl for post-harvest application will reduce the cost of fungicide treatment and provide several advantages over T.B.Z. Fruit treated with benomyl will not sporulate and inoculations due to injury after fungicide treatment are controlled (Tugwell and Wicks 1969).

Other Benzimidazole Fungicides

N.F. 44 and B.C.M. are satisfactory alternatives for post-harvest treatment of citrus (Rippon 1972) but no commercial advantage over using benomyl has been demonstrated.

Pre-harvest Application of Citrus Fungicides

Benomyl has shown promise overseas for pre-harvest

application for control of post-harvest decay (Brown 1968) and recently in Australia (Wicks, unpublished report). Reduction of decay from 90% to 33% in mechanically injured fruit was obtained. The need for an additional post-harvest treatment and the high costs of pre-harvest sprays may limit the use of this technique.

Diphenyl Wraps

Diphenyl wraps are not required if fruit is protected with T.B.Z. or benomyl. Trials at Gosford and in South Australia have shown T.B.Z.-treated unwrapped fruit to be as well protected as fruit subjected to the full S.O.P.P. diphenyl procedure. A gradual phasing out of diphenyl and wraps is expected.

Future Research

If benomyl is to be used successfully a simple technique for analysis of benomyl concentration is required to ensure export fruit receives adequate fungicidal protection.

With the introduction of selective fungicides other fungi such as *Alternaria* may be of increased importance. Resistance to benzimidazole fungicides may be compensated for by the use of growth regulators such as 2-4D and G.A.

Ethylene free storage atmospheres may allow long term storage of lemons and oranges. The effective fungicides now available will allow maximum exploitation of other post-harvest techniques.

The possibility that the benzimidazole group of fungicides may have a short commercial life must be considered. The possibility of resistant strains of *Penicillium* developing will ensure the testing of promising post-harvest fungicides for citrus.

Pome Fruits

Recent adoption of several new post-harvest techniques for handling and storage of apples and pears has increased the need for chemical control of fruit decay. In the past, post-harvest fungal wastage was of secondary importance to physiological disorders (Leggo 1968). High humidity controlled atmosphere storage, hydrocooling, water submergence dumpers in packing lines, and pre-storage treatment with liquid scald inhibitors have reduced the incidence of the physiological disorders - scald, breakdown, and Jonathan spot - and increased the danger of fruit inoculation and rot development during storage.

Post-harvest treatment of apples and pears with S.O.P.P. to control *Penicillium expansum* (Eckert and Sommer 1967) and

pre-harvest spraying for *Gloeosporium* rots, especially lenticel rotting, have in the past been unsuccessful. The requirements for an effective post-harvest fungicide for apples must include the ability to reach invading organisms situated in the innermost parts of the lenticel (Edney 1970).

Both thiabendazole and benomyl have systemic properties, but there is no evidence of translocation within the tissues of harvested fruit. The penetrant properties of both fungicides have been well demonstrated by their ability to control blue mould (*Penicillium expansum*), grey mould (*Botrytis cinerea*) and target rot (*Gloeosporium album*), when applied as a post-harvest dip treatment (Bondoux 1967; Dewey 1970; Blanpied and Purnasiri 1970; Pratella and Tonini 1969).

Both fungicides are compatible with the scald inhibitors D.P.A. and ethoxyguin (Cargo and Dewey 1970) and can be applied together without additional handling of the fruit.

Lenticel rotting of Golden Delicious and Granny Smith apples and blue mould of pears are controlled if fruit is dipped immediately after harvest (Tugwell 1971). Thorough mixing of the fungicide in the dip tank prior to the commencement of dipping is required. Once mixed the action of immersing bins maintains the fungicide in suspension. A 'stripping' rate of 0.75 oz of thiabendazole per 100 bushels of fruit dipped occurred when bulk bins were immersed in thiabendazole (Dahlenburg and Tugwell 1972).

Thiabendazole is extremely effective in controlling decay of mechanically harvested apples (Thomas and Blanpied 1971). The rotting of pears during ripening, prior to cutting for drying can be controlled by dipping the green pears in thiabendazole or benomyl soon after harvest (Tugwell and Dahlenburg 1972).

Future Research

By using effective post-harvest fungicides new techniques for the post-harvest handling of pome fruits which have created conditions more favourable for fruit decay have been adopted without increasing fruit losses.

The range of fungicides available is adequate for controlling post-harvest rots of pome fruits. The correct application of these fungicides to fruit intended for prepackaging or transport to market requires further research.

Stone Fruit

Brown rot (*Sclerotinia fruticola*) and *Rhizopus* rot (*Rhizopus vigricans*) are the fungi chiefly responsible for post-harvest losses of stone fruits. Prior to 1968 only limited success in the control of these rots was achieved with inorganic sulphur (Haller 1952), S.O.P.P. (Smith and Redit 1962)

and 2-amino butane (Eckert and Kolbezen 1964).

At the 1968 Fruit and Vegetable Storage Conference Tripp and Beattie reported the effectiveness of thiabendazole and benomyl as post-harvest dips for controlling brown rot of peaches. D.C.N.A. (dichloran) is the only fungicide known to give consistently good control of *Rhizopus* rot (Dewey and Maclean 1962; Stone *et al.* 1971). In his review of future research on post-harvest fungicides for stone fruits, Leggo (1968) suggested that pre- and post-harvest applications of benomyl in combination with a post-harvest treatment with dichloran should be investigated.

Subsequent research has shown that, provided recommended pre-harvest spray schedules are carried out, a combined post-harvest dip treatment of 500 p.p.m. benomyl and 400 p.p.m. dichloran as soon as possible after harvest will control both fruit rots, (Beattie and Outhred 1970; Fripp and Dettman 1969; Kable 1971; Stone, Wade and Beattie 1971). Both chemicals have been cleared for post-harvest application to peaches and approval for use on other stone fruits is expected.

The reported slow breakdown of benomyl and NF 44 in water to the fungitoxic compound methyl benzimidazole-2-carbonate (Clemons and Fisler 1969; Selling *et al.* 1970) has led to further work by Koffmann (1972) to determine the effect of the age of the dip solution on the effectiveness of post-harvest treatment for control of brown rot. Significant increases in effectiveness of benomyl and NF 44 were obtained by mixing the fungicides up to 8 days before application.

Future Research

Further investigation of the properties and mode of action of the benzimidazole fungicides in controlling brown rot is necessary to determine the most efficient and effective methods of application.

Further research is required to find an alternative to dichloran for the control of *Rhizopus*. This chemical leaves a visible residue on treated fruit if used at a concentration greater than 400 p.p.m.

Grapes

Wastage in grapes during cool storage and marketing is mainly caused by earlier infections in the vineyard by the fungus *Botrytis cinerea*. *Botrytis* will develop at temperatures as low as 30-32°F in berries which were infected in the field and spread through the bunch to form nests of decayed berries (Eckert and Sommer 1967; De Swart and Louw 1968). Commercial control of wastage is achieved by a combination of pre-harvest fungicides to control field infections and repeated post-harvest fumigation with sulphur dioxide. Research during the

last 4 years has been directed towards more effective and economical use of sulphur dioxide generators and packaging materials.

Beattie and Outhred (1970) obtained satisfactory results by wrapping individual bunches of grapes in tissue paper and then packing in boxes lined with wood-wool and pellets of sodium metabisulphite to slowly release SO_2 . A trial shipment from Sydney to Vancouver in 1968 out-turned in excellent condition.

Sulphur dioxide at high concentrations causes visible injury to grapes and bleaching of stems. Shattering (separation of berries from the bunch) and fungal infection of stems is controlled by fumigation with SO_2 , but not by post-harvest dipping. Post-harvest dipping in benomyl controls *Botrytis* but removes the bloom and spoils the appearance of the grapes (Dahlenburg, unpublished data).

Gentry and Nelson (1968), have developed a two stage in package generator of sulphur dioxide which can be included in a plastic lined package for the control of decay of table grapes. An initial fast release of SO_2 is obtained from small pockets of granular NaHSO_3 covered with one sheet of Kraft paper. A slow and continuous release for several weeks is then obtained from pockets of NaHSO_3 covered with polythene coated Kraft paper.

Trials in Australia by Wade (1971) have shown the commercially available 'Grape Guard' generator available from California provided an effective and reliable method for storing grapes for several months. The use of this product as an alternative to other methods of applying sulphur dioxide may depend primarily on cost. The 'Grape Guard' generator can be purchased at a cost of \$50.00 per 500.

Future Research

Further research is required to determine the effectiveness of combining pre-harvest treatment with benomyl, and post-harvest use of 'Grape Guard'. Marketing research is necessary to determine the future for stored table grapes in Australia and assure a return on the costs of the storage techniques now available. Condensation in packages and post-storage sulphur dioxide injury require further investigation.

Bananas

Fungal wastage of bananas during transport and marketing is principally due to the fungi *Nigrospora musae* (squirter and black end) and *Gloeosporium musarum* (anthracnose). Research in Australia has demonstrated that suspensions of 140 to 1,000 p.p.m. thiabendazole are far superior to salicylanilide

for controlling these fungi (Scott and Roberts 1967). Commercial use of T.B.Z. followed the granting of approval for post-harvest use in 1969. More recently benomyl has been shown to be more effective than T.B.Z. in controlling stem end diseases under commercial conditions (Long 1970).

The effective control of both fungi has enabled the use of plastic bags and ethylene absorbents for the transport of bananas at ambient temperatures to distant markets (Scott and Roberts 1967). Delayed ripening, reduced weight loss, and reduced mechanical injury were some of the benefits obtained from the combination of new packaging techniques and treatment with T.B.Z. prior to transport from Queensland to Auckland and Adelaide (Scott *et al.* 1971). Recent research has shown that premature ripening of bananas caused by *Colletotrichum musae* infection can be controlled by using effective post-harvest fungicides (Peacock 1972).

Future Research

Practical application methods and techniques for obtaining effective fungicidal treatment at minimal cost to the grower are required. The adoption of new post-harvest techniques will require effective application of the post-harvest fungicides now available.

Vegetables

Despite substantial advances in the development of fungicides for the control of post-harvest diseases of fresh fruits little progress has been made in the field of post-harvest diseases of vegetables (Eckert 1969). Development of a suitable post-harvest bactericide to control soft rot organisms is necessary because of the favourable conditions imposed by the prepackaging of vegetables (Lund 1971).

Summary

During the last 4 years the effective benzimidazole fungicides thiabendazole and benomyl have been approved for post-harvest application to fruit. Renewed confidence in the chemical approach to post-harvest disease problems has led to the successful application of new technology to the post-harvest handling of fruit and vegetables.

Research has concentrated on developing new techniques for fungicide application, especially to take advantage of the unique biological properties of the new materials.

Several chemically similar benzimidazole fungicides which contain a similar fungitoxic principal to benomyl (NF 44 and B.C.M.) have been developed, but unless a commercial

advantage can be seen there does not seem to be any necessity for post-harvest application.

There still exists a demand for fungicide treatments to solve specific problems, especially as new technology is applied to the marketing of fresh fruit and vegetables.

The possible development of resistant strains of fungi must not be overlooked, especially with the current dependence on the benzimidazole group of fungicides.

Future research will create a continuous demand for new chemicals and techniques for controlling post-harvest diseases.

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Discussion

Depletion of T.B.Z. or benomyl in the dip tank usually happens very rapidly at the beginning of fruit dipping, then slows down. Although there is a method for checking the concentration and depletion rate of T.B.Z., there is no such method for Benlate.

Under laboratory conditions T.B.Z. and benomyl are effective at 125 p.p.m., but higher concentrations, such as 1,000 p.p.m. for T.B.Z. or 500 p.p.m. for benomyl are recommended for commercial applications, on the basis of semi-commercial trials. B.A.S. 3460F (BCM) is methyl benzimidazole-2-carbamate and is the breakdown product of benomyl and this may be why benomyl is more effective than T.B.Z.

A new water soluble chemical (ME89) could prove to be better than the wettable powder T.B.Z. or benomyl.

The manufacturers should improve the formulation of the wettable powder so that they will stand up to continued use as a post-harvest dip or spray.

BULK DIPPING OF CITRUS

L.E. Rippon*

Introduction

At the Fifth Australian Fruit and Vegetable Storage Research Conference, Leggo (1968) in his review paper on chemical control of fungal wastage suggested that at that stage existing materials such as sodium ortho-phenylphenate (SOPP), 2-aminobutane (2-AB) and its salts, thiabendazole (TBZ) and Fungicide 1991 (or Benlate^(R) as it is now known) should adequately cater for citrus post-harvest needs, especially in respect to the control of *Penicillium* moulds.

It was also said that research in the immediate future could concentrate on the improvement of techniques of application, and that with substances such as 2-AB salts and TBZ, an automated spray or flood treatment of fruit in bulk bins would now be possible as it arrived at the packing house.

This paper deals with the use of TBZ as a bulk dip for citrus on arrival in the packing house, reporting on experiments carried out from the Citrus Wastage Research Laboratory, Gosford.

Mode of Infection by *Penicillium Digitatum*

Infection by *Penicillium digitatum* can occur any time during or after harvest of the fruit, the inoculum in the form of fungal spores being present on the surface of healthy fruit before harvest. Spores on the fruit are stimulated to rapid germination, and the fungus infects the fruit through injuries. Thus when the fruit is treated with a fungicide in the packing house, it may have a series of infections at different stages of development, depending upon what time after harvest each injury was received.

Prompt Treatment for Effective Control

The effectiveness of all post-harvest fungicide treatments depends very much upon prompt treatment of the injury points. The delay which can be tolerated between harvest and treatment varies with seasonal differences and temperatures but should be no longer than 24-36 hours in summer or 3-4 days in winter (Seberry 1969). Delays beyond these maximum times, often unavoidable, do occur and are reflected in wastage occurring before normal packing house treatment and poor mould control even after the application of this in line fungicide.

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Outline of Trials

These were undertaken in a commercial packing house where facilities such as a large tank, fork lift and fork lift attachment were available for handling bulk bins. Treatments were applied to two classes of fruit, that which was naturally spore loaded and fruit which had been artificially wound inoculated with a suspension of spores of *P. digitatum*.

Five mesh bags each with about 30 artificially inoculated fruit were distributed throughout bulk bins of naturally spore loaded fruit delivered for normal packing. The wound inoculated fruit was not of the same source as the bin fruit, but it was treated within 24-36 hours of harvest to determine the effect of prompt treatment of injured fruit.

Three bins were used in each replicate, one being treated with water only, one in TBZ for 30 seconds, and a third TBZ for 2 minutes. Several replications were carried out with each concentration of TBZ, using both Washington Navel and Valencia oranges. After allowing surplus free liquid to drain back into the dipping tank, the bins were stacked on the packing house floor where they remained until the water treated wound inoculated fruit developed symptoms of mould infection. Wastage assessments were then made.

Fungicidal Efficiency

The results with Navel oranges are set out in Table 1.

TABLE 1
Green Mould Wastage in Navel Oranges After
Bulk Bin Treatment

Treatments	Per cent mould in artificially inoculated fruit	Numbers of spore loaded bin fruit infected with mould
<u>TBZ 1000 p.p.m.</u>		
- 30 sec dip	1.0	32
- 2 min dip	0.8	31
<u>Water only</u>		
- control	97.2	276
<u>TBZ 500 p.p.m.</u>		
- 30 sec dip	1.5	48
- 2 min dip	0.5	26
<u>Water only</u>		
- control	99.3	287

Both concentrations of TBZ effectively controlled mould in artificially inoculated fruit and significantly reduced wastage in the spore loaded bin fruit. There was however, considerable variability in the degree of control in this latter fruit, reflecting possibly, differences in time between harvest and application of the fungicide.

Because the 500 p.p.m. dip was as effective as the 1000 p.p.m. in controlling mould, the latter concentration was not used in the later trials with Valencia oranges. A dip of 250 p.p.m. was used instead.

The results with Valencia oranges are set out in Table 2.

TABLE 2
Green Mould Wastage in Valencia Oranges After
Bulk Bin Treatment

Treatments	Per cent mould in artificially inoculated fruit	Numbers of spore loaded bin fruit infected with mould
<u>TBZ 500 p.p.m.</u>		
- 30 sec dip	0.1	33
- 2 min dip	0.9	29
<u>Water only</u>		
- control	100.0	110
<u>TBZ 250 p.p.m.</u>		
-30 sec dip	21.2	86
-2 min dip	17.7	70
<u>Water only</u>		
- control	99.8	184

With Valencias the 500 p.p.m. concentration was as effective in controlling mould in artificially inoculated fruit as it was with Navels, but the result with spore loaded bin fruit was not as good (Table 2). An explanation might be that in warmer weather, when the Valencias were harvested, a higher percentage of the infections were beyond the point of being arrested by the

fungicide by the time they were treated in the packing house, than during the cooler Navel season.

There was again considerable variability in the degree of control in spore loaded fruit, which could reflect differences in care exercised by growers when handling fruit, and again differences in time between harvest and application of the fungicide.

Overall, 250 p.p.m. TBZ in these trials did not perform as well as the higher concentration on both artificially inoculated and spore loaded fruit, although several of the replicates were effective.

Residues

(a) Single treatment in bulk

Surface skin deposits were determined, and because they were made within 5 days after dipping they were a reliable measure of whole fruit residues (Glennie-Holmes 1972). Deposits were variable throughout bins, there being greater variability between deposits at the bottom of the bins than at the top. The mean value for deposits at the top of the bins was lower than that at the bottom.

Over the trials a dip of 1000 p.p.m. gave a mean fruit deposit of 4.8 p.p.m., one at 500 p.p.m. gave a deposit of 2.6 p.p.m., whilst a dip at 250 p.p.m. gave a deposit of 1.5 p.p.m.

Except for the lowest concentration dip these mean deposits are in excess of the 2.0 p.p.m. whole fruit tolerance for citrus, but they should not be intolerably high if the washing-scrubbing operation in the packing house line is efficient.

(b) Treatment in bulk followed by packing line treatment

More pertinent perhaps is the residue level after dipping in bulk followed by packing line operations including a second application of TBZ.

Using a dip at 500 p.p.m. a bin of fruit from each of eight different growers' was treated. From these bins random samples were taken before and after washing and after flood application of TBZ at 1000 p.p.m. The mean surface deposits for these samples were 3.4, 0.4 and 2.1 respectively. The residues after dipping were very variable but the washing process conveniently reduced these levels to the mean of 0.4 p.p.m. The same fruit when given a single application of TBZ at 1000 p.p.m. had a mean residue level of 1.9 p.p.m.

Dip Depletion and Usage Rate

There was a gradual depletion of the TBZ in the dip tank but the depletion rates recorded ranged from about 0.5 to 2.5 per cent of the initial concentration for each bin dipped.

The amount of liquid removed from the tank after dipping depended on several factors, but draining time seemed most important. When 2-3 minutes were allowed for this, the amount of liquid taken out by each bin and contents was of the order of 1.5 gallons. In the trials an initial volume of 300 gallons was used, and after about 20 bins were dipped the addition of 30 gallons was found necessary to readjust the volume to a satisfactory working level.

Conclusion

The trials have shown that bulk dipping should be considered in either grower or packing house operations when there are likely to be delays in excess of those recommended between picking and the usual fungicide treatment. The application of a prompt treatment would significantly reduce mould wastage and improve overall keeping quality.

A dip of 500-1000 p.p.m. should be adequate to provide the necessary protection against *P. digitatum*. TBZ is removed in the washing operation and final deposits from the double treatment should be only slightly in excess of those from the single normal packing line treatment.

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A COMPARISON OF FOUR SYSTEMIC FUNGICIDES FOR POST-HARVEST TREATMENT OF CITRUS

L.E. Rippon^{*}

Introduction

The citrus industry has available to it in thiabendazole (TBZ) a very good post-harvest fungicide for the control of *Penicillium* moulds. Two other compounds which have been tested and found effective are benomyl and thiophanate-methyl, but their registration for use on citrus is still being awaited. A fourth compound recently tested is benzimidazole carbamic acid methyl ester (BCM) formulated as a wettable powder and designated as BAS 3460 F.

The success of TBZ as a post-harvest fungicide has apparently stimulated development of chemically related compounds for similar use. Of the four reported on here, three are benzimidazole derivatives, two of which breakdown to give a benzimidazole molecule, and the fourth is the breakdown molecule.

The chemistry of the four is:-

1. Thiabendazole - 2-(4-thiazolyl)-benzimidazole.
2. Benomyl - 1-(butylcarbamoyl)-2-benzimidazole, which quickly hydrolyzes in aqueous solution to form benzimidazole carbamic acid methyl ester (BCM) which is an active fungicide.
3. Methyl-thiophanate (NF 44) - 1,2-bis(3 methoxycarbonyl)-2-thioureido benzene, which also breaks down in water to give BCM.
4. BCM - Benzimidazole carbamic acid methyl ester.

The work reported here was that of two trials undertaken to compare the relative efficiency of the four compounds in controlling *Penicillium digitatum* (green mould) in oranges.

Outline of Trials

Washington Navel oranges from three different growers were artificially wound inoculated with spores of *P. digitatum* by puncturing the skin with a nail that protruded $\frac{1}{8}$ " through

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a cork, the nail having previously been dipped in an aqueous suspension of the spores.

After remaining at ambient temperature for 24 hours each grower's fruit was randomized into 17 samples of about 40 fruits each. The fungicide treatments were then applied as a 30-second dip, using one sample per treatment for the 17 treatments indicated in Table 1.

Details of the 17 treatments are:-

- 1 - 4 Thiabendazole as 90 per cent w/w wettable powder, Tecto 90^(R) (see Table 1 for concentration).
- 5 - 8 Benomyl as 50 per cent w/w wettable powder, Benlate^(R) (see Table 1 for concentration).
- 9 - 12 Thiophanate-methyl (NF 44) as 70 per cent w/w wettable powder, Topsin M^(R) (see Table 1 for concentration).
- 13 - 16 Benzimidazole carbamic acid methyl ester as 50 per cent w/w wettable powder, BAS 3460 F (see Table 1 for concentration).
- 17 Water control.

After treatment the samples were held in boxes for one week at 23°C (74°F) and then wastage assessments were made (Table 1). An infected fruit for counting purposes, was one showing typical mould symptoms originating from the inoculation point.

Results

Green mould (*P. digitatum*) breakdown in water treated control fruit was almost 100 per cent. The fungicide treatments all provided control to some extent but differed in the concentration required for equivalent effectiveness.

Regression equations relating wastage and concentration were established, and the relative potencies of the fungicides were calculated from these equations. Relative to benomyl, thiabendazole was 0.27 times as effective with 95 per cent fiducial limits of 0.20 and 0.36; methyl-thiophanate 0.08 times as effective with 95 per cent fiducial limits of 0.06 and 0.11; and BCM 1.05 times as effective with 95 per cent fiducial limits of 0.77 and 1.44.

TABLE 1

Relation Between Concentration and Per Cent
Green Mould (*Penicillium digitatum*) After
Treating Washington Navel Oranges with
Four Fungicides

Treatment (30 sec dip)	Per cent <i>Penicillium</i> mould Mean in angles	
<u>Thiabendazole</u>		
4 p.p.m.	77.4	(95.2)*
12 "	67.4	(85.2)
36 "	21.3	(13.2)
108 "	8.8	(2.3)
<u>Benomyl</u>		
2 p.p.m.	69.3	(87.5)
6 "	39.7	(40.8)
18 "	14.1	(5.9)
54 "	6.3	(1.2)
<u>Thiophanate-methyl</u>		
5 p.p.m.	75.9	(94.1)
25 "	65.8	(83.2)
125 "	27.6	(21.5)
625 "	17.0	(8.6)
<u>MBC</u>		
1 p.p.m.	77.7	(95.5)
3 "	57.0	(70.5)
9 "	30.8	(26.2)
27 "	9.9	(3.0)
<u>Control</u>		
Water only	85.4	(99.4)
All values are means of 3 grower replicates x 2 times.		
*Retransformed means.		
S.E. mean in angles = ± 1.83 on 15 degrees of freedom.		

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(The text and table of this paper have been altered because of additional data being available since the original paper was submitted).

Discussion

The efficiency of BCM at low concentrations was well demonstrated. Benomyl was effective at concentrations lower than those for thiabendazole and thiophanate-methyl. In aqueous solution benomyl rapidly forms MBC (Clemons and Sisler 1969), whilst under various conditions, e.g. in tap water, thiophanate-methyl can be converted into the same compound (Selling *et al.* 1970). Vonk and Kaars Sijpesteijn (1971) concluded that it is not the thiophanate-methyl itself but MBC that is responsible for the fungitoxic effects. Work carried out by Koffman (1972) demonstrated that brown rot *Sclerotinia fructicola* (Wint.) Rehm, in peaches decreased significantly with increase in the period of standing of benomyl and thiophanate-methyl dip suspensions, in an *in vivo* situation. With aging, these two materials could conceivably improve in effectiveness in controlling *P. digitatum* in a similar situation.

The results reported here indicate that of the four materials tested, any one would be satisfactory for post-harvest treatment of citrus, at concentrations likely to be used commercially.

THE EFFECT OF DECOMPOSITION OF BENOMYL AND THIOPHANATE METHYL IN WATER ON THEIR CONTROL OF BROWN ROT OF STONE FRUIT

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Post-harvest rot due to *Sclerotinia fructicola* (Wint.) Rehm often causes serious losses in the marketing of peaches, but it can be controlled by dipping the fruit in fungicide suspensions.

Several workers have proved the effectiveness of benomyl and TBZ against *S. fructicola*. Preliminary work carried out at the Agricultural Research Station, Bathurst, New South Wales, during 1970/71 and 1971/72 seasons indicated that thiophanate methyl used at 4,800 p.p.m. also had some activity against *S. fructicola*.

Benomyl and thiophanate methyl slowly break down in water to methyl benzimidazole-2-carbamate, a fungitoxic molecule, reported by Clemons and Sisler (1969) and Selling *et al.* (1970) respectively. From this, it was decided to investigate the effect of this decomposition on the activity of both fungicides in the control of brown rot.

Three trials were carried out, at intervals of 4 days. On the first and second occasions (0 and 4 days after the preparation of the suspensions) peaches of the Glenalton variety, using units of 20 fruits per replicate, were dipped. Late J.H. Hale peaches, using units of 15 fruits per replicate, were used for the third dipping (8 days after preparation). On each day four replicates of fruit were dipped.

Benomyl was used as 50% w.p. formulation (Benlate^(R)) and thiophanate methyl as 70% w.p. (Topsin M^(R)). A non-ionic wetting agent (Kemul T 20^(R)) was added at 0.12 per cent in all treatments. During dipping the fungicide suspensions were constantly agitated.

Prior to the fungicide treatment, the fruit was inoculated with spores of *S. fructicola* by dipping in a spore suspension after three pin punctures were made in the apex of each fruit. The fruit was then air dried before fungicidal dipping.

Treatments comprised thiophanate methyl at 400, 800 and 1,600 p.p.m. and benomyl at 75, 150 and 300 p.p.m. Two units per replicate were left untreated to provide a measure of the

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level of infection.

The fruit was dipped for 30 seconds, air dried and incubated for 5 days at 21°C, after which the number of fruit with brown rot lesions was determined. The counts of rotted fruit are presented in the Table:

Counts of Fruit Infected with *Sclerotinia fructicola*

Mean of Four Replicates

T R E A T M E N T	Period after dip preparation		
	0 Days ⁺	4 Days [*]	8 Days ^φ
Untreated (1)	19.50	9.75	14.75
Thiophanate methyl, 400 p.p.m.	18.75	7.75	1.00
" " 800 p.p.m.	16.00	4.75	0.75
" " 1,600 p.p.m.	15.25	4.25	1.50
Benomyl, 75 p.p.m.	16.25	3.00	0.50
" 150 p.p.m.	13.75	2.50	0.50
" 300 p.p.m.	11.50	1.00	0.00
Untreated (2)	18.75	12.00	14.00

+ 20 fruits per unit

* 20 fruits per unit

φ 15 fruits per unit

Infection decreased with increase in concentration for both compounds. The regression lines for both fungicides were not significantly different on the different days.

Brown rot decreased significantly with increase in the period of standing of the dip after preparation and for the periods used here, the decrease was linear.

The most important observation made was the very significant improvement in the degree of control obtained with both fungicides 8 days after preparation of dipping suspensions as compared to treatments on the day of preparation. Also the effect of concentration on rot control was not as apparent in fruit dipped 8 days after preparation of the fungicidal suspensions.

Vonk and Kaars Sijpesteijn (1971) had previously demonstrated this type of effect with *Penicillium italicum* Wehmer, *Aspergillus niger* van Teighem and *Cladosporium cucumerinum* Ell and Arth, in liquid culture media, but no reference could be found of a similar effect in an *in vivo* situation.

The Bathurst results support the proposals of Vonk and Kaars Sijpesteijn that the fungitoxic activity of both benomyl and thiophanate methyl is related to the amount of the breakdown product, methyl benzimidazole-2-carbamate, present in the suspension.

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Discussion

The fact that these fungicides are more effective after standing for some time after preparation of the suspension throws doubt on earlier work in which the delay was not recorded. It seemed that once spores had gained entry to the fruit, as with inoculation or orchard and harvest wounds, it was the breakdown products which gave control. This would explain why old dips performed so well.

The recommended benomyl concentration for commercial use was questioned, as it was shown that good brown rot control was possible at 75 p.p.m. Even the need for a substantial safety factor would still allow dipping at much lower concentrations. The rate at which the breakdown product is formed in the Benlate

dip might be related to the type of fruit being dipped. This was supported by the observation that unused dip which had stood for 5 days showed less fungitoxic activity than dip which had been used.

Pre-harvest tree sprays with benomyl were less effective than dipping the fruit after harvest in New Zealand and Victoria.

GRAPE FUNGICIDAL AND PACKAGING TRIALS

I.D. Peggie^{*}

The production of table grapes has remained a small but important section of the Australian grape industry. Problems are rarely encountered in local marketing, unless rain or warm humid conditions cause the berries to split and allow development of *Botrytis cinerea*.

Little attempt is made to supply late varieties from storage. When storage is attempted it is usually without the use of fungicidal treatments, such as the sulphur dioxide gassing used in United States of America and South Africa. The use of benomyl pre-harvest spray schedules to control *B. cinerea* on the vine is rarely used except for export fruit.

Grape exporting has mostly been concentrated on markets in South-east Asia and Pacific Islands. However, a potentially good trade exists in UK/Europe and in North America, provided the outturn quality is high.

Recent grape packaging and fungicidal trials in Australia have been concerned with export grapes (Scott and Roberts 1965; Beattie and Outhred 1970; Wade pers. comm.). The problems occurring in export grapes vary somewhat according to the different markets. Places like Singapore require the fruit to have ample shelf life and be packed so that warming up is gradual and condensation occurring in the bunches is minimized. The longer hauls to North American and European markets, with shipping periods of 6 weeks, limit export to mid and late season varieties with good storage potential. Unfortunately the varieties which store well are usually fairly tough skinned and the high quality varieties are not easily exported.

Grape packaging experiments in Victoria were undertaken following the disastrous outturn in 1969. Most of the export had been of Ohanez grapes packed in wooden cases with granulated cork fill and powdered sodium metabisulphite fungicide. Wastage was particularly high, up to 75%, in the major markets of Manila and Singapore, and subsequent claims were made on the exporters.

The main complaints from the importers were:-

- (a) Rotting and deteriorating grapes and stems, evident on opening the cases, and
- (b) Subsequent discolouration of apparently sound fruit after a short exposure to warm air.

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The 1970 trials tested a number of different packs against the standard commercial pack as exported. These treatments all used tissue wrapped bunches packed into cases with a vented polythene liner. The fungicidal treatments used were sodium metabisulphite powder (15 g) sprinkled over the wrapped bunches; sodium metabisulphite tablets (20 x 190 mg) dispersed among the wrapped bunches; benomyl and thiobendazole dip treatments of 50, 1500 and 3000 p.p.m. for 2 minutes at 20°C. Shorter dip periods with 3000 p.p.m. of both materials were given at 35°C and 50°C. The metabisulphite tablets were first used many years ago in South Africa, and were recently found by Beattie and Outhred (1970) to be effective with wrapped bunches. They did not find TBZ sprays effective but a dip treatment was considered likely to be better, especially when the grapes were packed in polythene lined cases. Benomyl had previously been found to give excellent field control of *B. cinerea* in Victorian Ohanez grapes.

All bunches included one berry inoculated with *B. cinerea* incubated for 3 hours before treatment. It was found that many treatments had a fungicidal effect as the inoculated berries did not develop rot in those treatments, possibly because the incubation period was too short. All control bunches developed *B. cinerea*. All the treatments reduced the spread of rot, with less effectiveness from the lower concentrations or short dip periods with TBZ.

Stem blackening was caused by the hot dips with both benomyl and TBZ. The metabisulphite powder and tablet treatments showed some severe bleaching of the berries. Darkening of berries and the occurrence of depressed, shrivelled areas around the pedicel, with a strong sulphur taint, were noticeable in these treatments after a week ex cool store. The polythene liner reduced stem shrivelling and shatter and did not aggravate stem or berry mould.

The trial demonstrated the problems encountered in the 1969 export shipments. Poor distribution of powdered metabisulphite, presumably coupled with fruit having a high wastage potential, resulted in poor mould control. It also suggested that sulphur dioxide injury was caused by local high concentrations of the fungicide, possibly associated with weakened pedicel attachment due to excessive handling or delayed cooling.

The use of a polythene case or carton liner, together with the avoidance of localized concentrations of metabisulphite powder, better handling of the bunches and better field control of *B. cinerea* were suggested as worthwhile procedures to improve export outturn.

In the 1971 season, 'Grape Guard' pads were made available for testing. Developed in California (Nelson and Gentry 1966, 1968) the pads consisted of powdered sodium metabisulphite contained between paper in two layers, one to give a quick release of sulphur dioxide to build up an initial adequate gas concentration, the other to give a slow release of SO_2 over the storage period.

The pads were compared against metabisulphite tablet treatments in the standard fibreboard grape carton, in the export grape case both with and without a plastic liner, and in the plastic 'Corflute' carton. Each package held 10 kg of Ohanez grapes in tissue wrapped bunches.

All packs were given simulated export temperature treatments in storage and were held for 4 days at 24°C and 80% RH before examination. The Grape Guard pads gave slightly better rot control than the tablets. The fibreboard carton and the unlined wooden cases both gave bad shrivelling of the stems. When the plastic case liner or the plastic carton was used, stem shrivelling was slight but the fruit was wet with condensation. Under these conditions sulphur dioxide injury and tainting was severe. The two 'Grape Guard' pads or the 16 x 190 mg tablets used obviously provided too much SO_2 at the end of the storage period under the hot moist conditions of the simulated marketing period.

This trial supported the experience of Nelson *et al.* (1970) who found problems of SO_2 injury, and suggested that generators with a slower release rate were needed. The trial also demonstrated the need for some form of moisture loss control within the package, provided that it can avoid the hazard of excess SO_2 build up in the marketing period. Nelson also suggests the use of polythene stack covers over unlined or vented cartons, enabling a rapid build up of SO_2 to desirable levels immediately after packing, but when shipped as single cartons without the cover these would not be liable to build up injurious SO_2 levels.

Future development

Most experimental work has been concerned with variations in the use of SO_2 producing materials. Concern over SO_2 levels in fresh fruit, as recently expressed by Germany, and the problems of controlling the concentration within the package under all conditions occurring during transport and marketing, suggests that alternative fungicidal treatments should be investigated. The 1970 Victorian trials with benomyl indicated a likely treatment. Loss of bloom, and the appearance of residue on the fruit, are undesirable side effects of dipping.

It may be feasible to apply benomyl or other fungicides as dusts, as sprays or mists followed by rapid drying before the fruit is handled, or as a vapour treatment. Preference should be given to materials with a rapid rate of breakdown, provided they have a high fungicidal activity against *B. cinerea*.

Packaging now appears to have standardized on bunch wrapped treatments, mostly in fibreboard cartons but also using small wooden cases similar to the South African grape case, holding about 7 to 10 kg. These packs are attractive in presentation, and allow bunches to be easily handled for sale. Tight fill packing, using a vibrated pack with a pressure pad to prevent fruit movement during transport, is being investigated in U.S.A. (Nelson 1969, pers. comm.). This method offers a lower packaging cost and makes best use of the space available in the package.

All packs should have some form of moisture loss control, either as vented polythene liners, heavy waxed liners or coated carton material. None of the new packs, however, give the same slow warming up and avoidance of condensation problems as the standard cork pack which remains the required pack in tropical areas. Obviously we need to have different packs suited to the particular conditions of the various available markets.

One problem which remains in Australia is the lack of good cool storage facilities in the grape producing areas. Delays in pre-cooling aggravate the problems of moisture loss and mould control. Bunch trimming procedures are also rough, and subject the fruit to excessive handling, which aggravates mould, stem blackening and drying problems.

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Discussion

Poor outturn after export or local storage was frequently associated with a combination of poor handling and SO₂ damage.

There was a comment that the use of SO₂ minimized bunch shatter and retained good stem appearance while some fungicides tended to darken stems. Mr Peggie was not convinced that SO₂ was the best treatment available. T.B.Z. dipping and packing in polyethylene-lined containers gave excellent results.

The use of fungicidal sprays at flowering to reduce *Botrytis* infection in the floral remains is an important part of control of wastage after harvest. Experiments to reduce such latent infection by using benomyl and thiophenate-methyl are in progress.

Regular spraying of the vines, trimming of the bunches in the field, rapid cooling and prompt packing would go a long way to producing better outturn after storage.

EFFECT OF RIPENING TEMPERATURES ON THE SHELF LIFE OF BANANAS

T. Trochoulis*

Introduction

Ripening temperatures for bananas were investigated first in Australia by Young *et al.* (1932). In reviews, Stevenson (1954) and Hall (1962) essentially recommended the same range of pulp temperatures, i.e. 21°C in summer and 19°C in winter. The Banana Research Advisory Committee, set up to direct and finance post-harvest research in bananas, recently recommended pulp temperatures ranging from 14.4°C to 21°C for ripening bananas in Australia (Anon. 1971).

The United Fruit Company, one of the two major companies distributing bananas in the United States of America, established a ripening schedule covering a 4 to 10 day period using a range and combination of temperatures from 14.4°C to 17.8°C for Gros Michel and Valery bananas (Anon. 1964).

Previous Work at Alstonville

Four experiments conducted at the Alstonville Tropical Fruit Research Station by L.E. Rippon (unpublished data) on summer and winter maturing fruit in 1969 and 1970 showed that the main effects of days ripening, temperature and days holding after removal from the ripening room were highly significant for both skin colour and pulp firmness over all seasons. In these experiments, temperatures of 17.8°C and 21.1°C were used for ripening of both summer and winter fruit. After removal from the ripening room, summer fruit were held at 21.1°C and 26.7°C and winter fruit at 13.3°C and 18.3°C .

Current Trials

A further trial was conducted with autumn maturing fruit (March-April, 1972) to observe the effect of a range of temperature conditions during ripening on the shelf life of bananas. Particular attention was paid to include a low ripening temperature (15.6°C), as used overseas, to observe whether this treatment would produce fruit with a longer shelf life.

The experiment was made up of two replicates involving a total of 810 fruit. Nine bunches were harvested in each replicate from an irrigated plantation growing on red volcanic

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soil (Wollongbar clay loam). Individual fruit (fingers) were taken from the 2nd, 3rd, 4th and 5th hands after discarding the 'wing' or extreme end fingers. After washing and dipping in benomyl at 400 p.p.m., the fingers from each replicate were randomly divided into 45 lots of nine fruit.

The fruit was placed in 1 m³ ripening cabinets at temperatures of 15.6°C, 17.2°C and 18.9°C and a R.H. between 200-300 p.p.m. Ripening was initiated with ethylene gas at a rate of 200-300 p.p.m. A second charge of ethylene was applied the following day after the fruit had been ventilated for 10 minutes.

After 3 days, 27 fingers were removed from each ripening chamber and three lots of nine fruit placed in each three storage cabinets at temperatures of 15.6°C, 21.1°C and 26.7°C. The R.H. was maintained between 70-80%. The same procedure was repeated on the 4th, 5th, 6th and 7th days.

Pulp firmness was measured with a modified ring-maturometer (Mitchell *et al.* 1961) on sample fruits at the Standard Colour Indices (Anon. 1969) of stages 4 and 6, by taking a transverse slice 1 cm thick from the centre of each banana from which the peel was removed.

Results

Figure 1 shows the means for the times taken by bananas to reach colour stages 4 and 6 in response to the various combinations of ripening and storage temperature regimes.

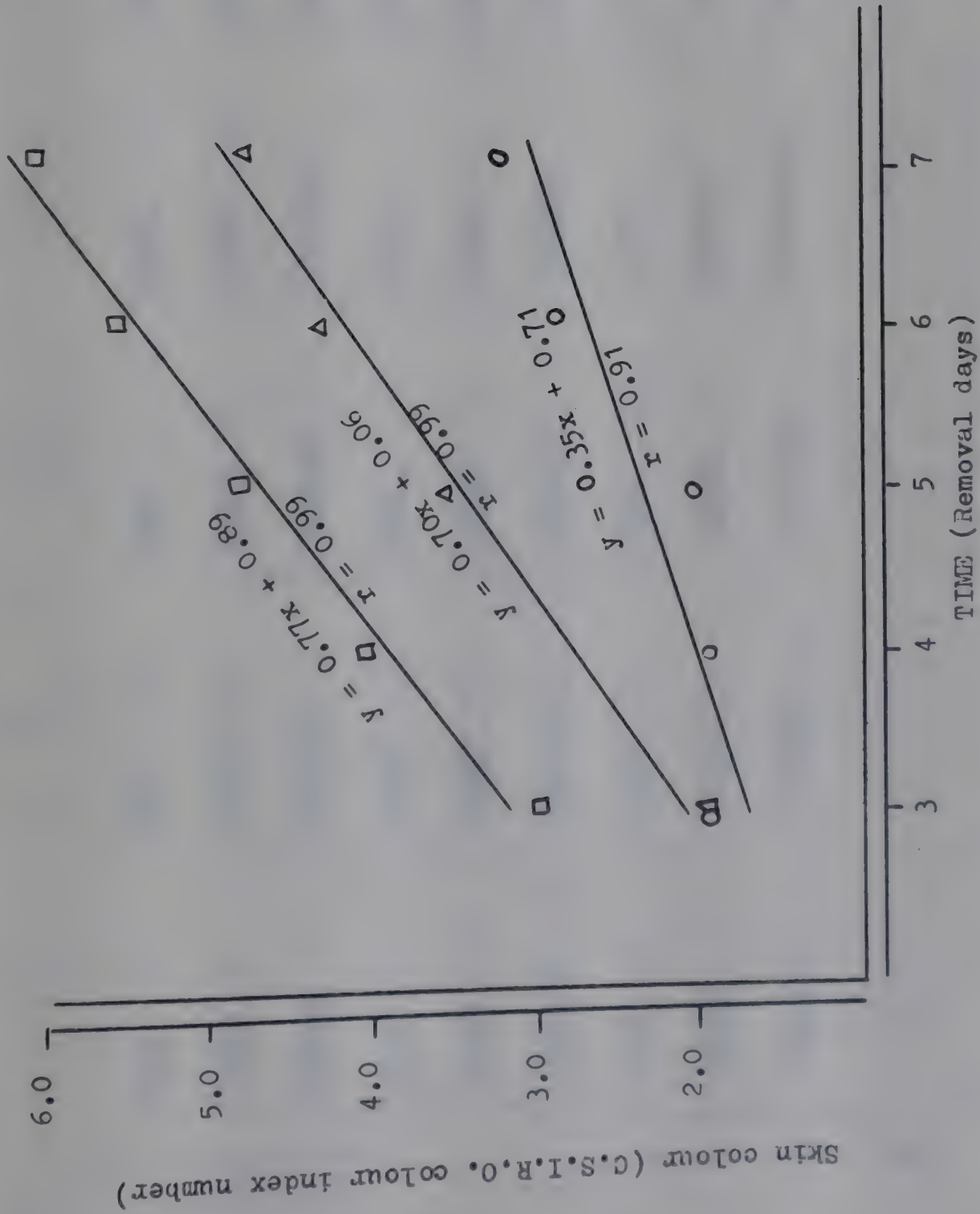
Figure 2 relates skin colour to ripening temperatures for fruit removed from the ripening cabinets from 3 to 7 days.

Figure 3 relates pulp firmness readings taken on bananas at colour stage 6 with the times taken by the fruit to reach this colour in response to the temperature regimes studied.

The following general observations can be made on inspection of the figures:-

- (1) The higher the ripening temperature, the shorter the total life of the fruit (i.e. the time taken to reach colour stage 6) and the shorter the time to progress from colour stage 4 to stage 6.
- (2) The shelf life of the fruit was very largely determined by the temperature at which ripening was initiated and holding temperatures subsequent to removal from the ripening room had little influence. (In many cases fruit colour was so advanced at the time of removal from the ripening room that effects of subsequent storage could not be assessed).

Figure 2 - The relation of skin colour with ripening temperature.



KEY

□ = 15.6°C Ripening
Δ = 17.2°C Ripening
○ = 18.9°C Ripening

Fig. 1 - Means of days taken for bananas to reach colour stages 4 and 6 and their differential (shelf-life) in response to various ripening-storage temperature regimes and removal dates (readings = means of 6 fruit).

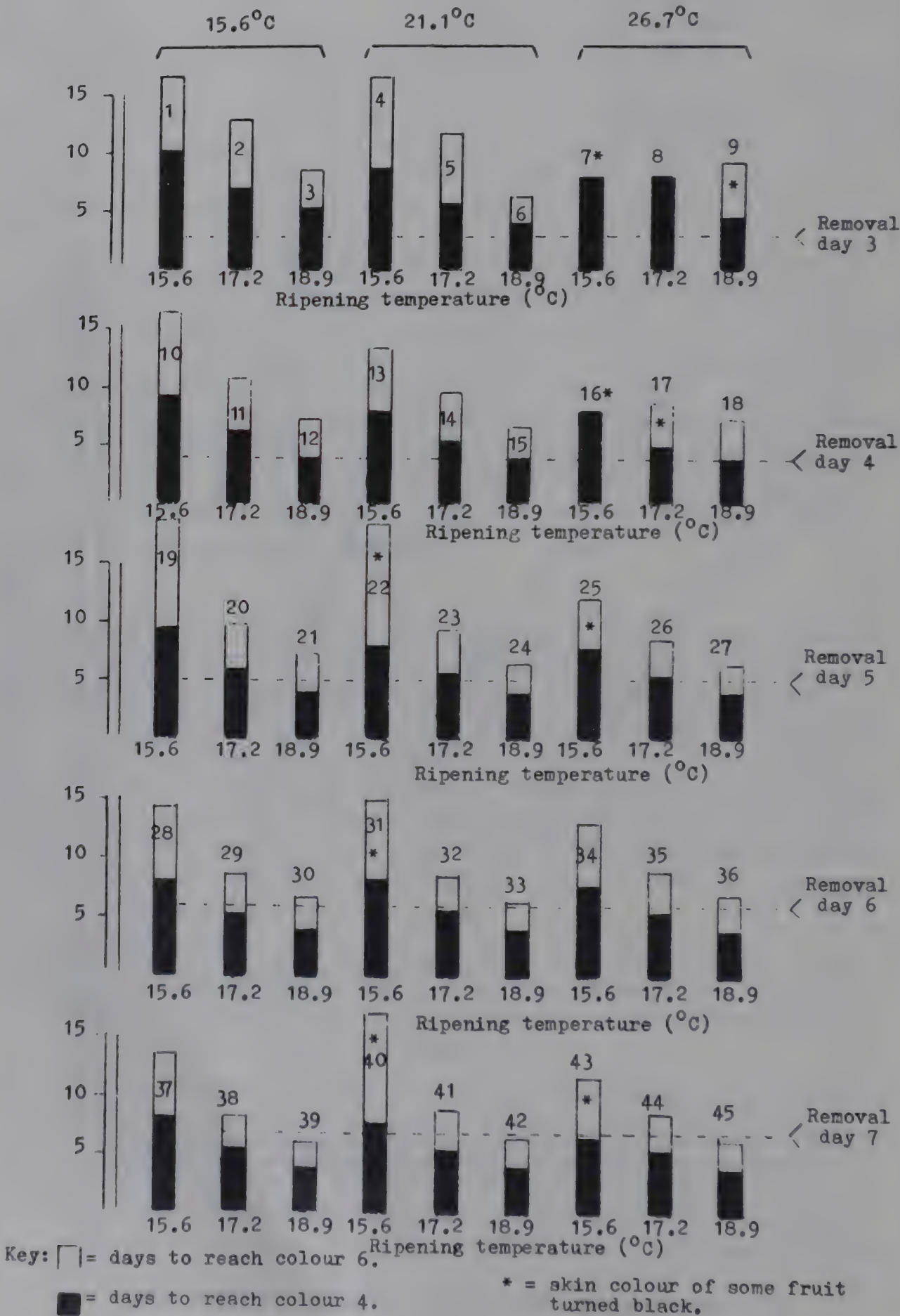
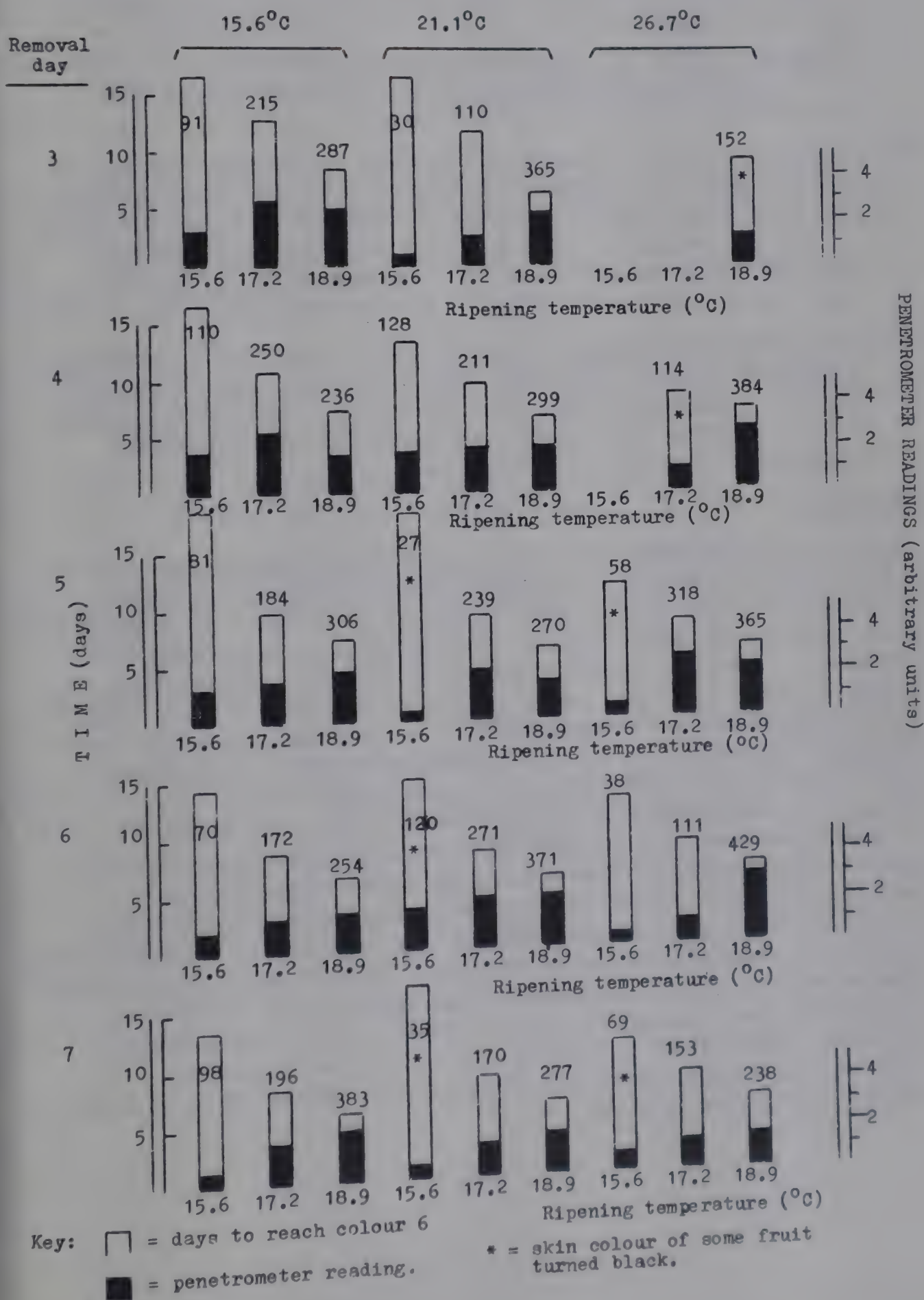


Fig.3 - Means of penetrometer readings at colour stage 6 and ripening ratio (penetrometer reading/number of days required to reach colour 6 ($\times 10^{-3}$))



- (3) There was a trend for the life of fruit to be shortened as the length of time in the ripening room was increased.
- (4) There was a tendency for fruit ripened at higher temperatures to have a firmer pulp when colour stage 6 had been reached than fruit ripened at lower temperatures. Thus the ratio of the penetrometer reading to the number of days required to reach colour 6 increased as the temperature of ripening increased.
- (5) Several lots of bananas which were initially ripened at 15.6°C and then removed to higher storage temperatures of 21.2°C and 26.7°C (Figure 1) failed to ripen normally to colour stage 6. The peel of this fruit blackened and the pulp became 'boiled'. Fruit held at 15.6°C for the whole period ripened slowly but normally.
- (6) The rate of ripening for the 18.9°C and 17.2°C temperatures was almost parallel and double the rate of the 15.6°C temperature regime (Figure 2). The latter slow rate suggests that 15.6°C is close to the threshold value for ripening of this fruit.

Discussion

The trial indicated that for autumn maturing bananas grown at Alstonville, the life of fruit after harvest was mainly determined by the temperature at which ripening was commenced. Colour developed more rapidly as ripening temperatures were increased. However, fruit ripened at higher temperatures tended to have a firmer pulp, relative to skin colour, than fruit ripened at low temperatures. A similar situation was previously observed in winter maturing fruit ripened at 18.3°C and 21.1°C (L.E. Rippon, unpublished data).

Ripening was adversely affected when fruit was held initially at low temperatures and subsequently removed to higher temperatures. These results would suggest that considerable risk would be involved if commercial ripening was carried out at temperatures as low as 15.6°C , especially during the warmer periods of the year. Generally satisfactory results were achieved by commencing ripening at 17.2°C , although in two instances fruit subsequently removed to a much high temperature (26.7°C) did not ripen normally.

Further investigations are planned to examine more closely some of the above results.

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Discussion

Bananas ripened poorly when ripening at 15.6°C was partial (to stage 2) with completion (to stage 6) at 21°C . Under such ripening conditions fruit were probably removed from 15.6°C at a stage in maturation coinciding with the respiratory climacteric. Subsequent ripening to stage 6 progressed but fruit flesh was firmer, possibly because fruit were sensitive to temperature change at the time of the climacteric peak of respiration. The effects of temperature changes during ripening are not clear, it is important that they be clarified in the interests of getting good bananas to consumers in diverse climates.

EFFECT OF COLLETOTRICHUM MUSAE INFECTION ON
THE GREEN-LIFE OF BANANAS

B.C. Peacock^{*}

Diseases caused by the organism *Colletotrichum musae* are prevalent in most banana growing regions of the world. The organism has been shown to cause wastage of bananas through both latent and non-latent infections. Wastage from these diseases can be severe on Australian markets (Young *et al.* 1932) and is generally a result of the spoiled appearance of infected fruit. Recent studies at the Sandy Trout Food Preservation Research Laboratory have shown that the occurrence of *C. musae* infection in preclimacteric fruit has another and possibly more detrimental effect. In such fruit, the disease, which is a result of wound infection rather than latent infection, has been shown to drastically shorten the green-life of the fruit.

There was some previous evidence for this. Tomkins (1931) observed that rots due to *C. musae* possibly affected the 'rate of ripening' of bananas, but stated there was no good evidence for this. It is not clear whether by 'rate of ripening', this author was referring to the duration of the preclimacteric phase (green-life) or to the rate at which ripening proceeds once it has commenced. Wardlaw and McGuire (1932) have apparently shown that rots due to *Botryodiplodia theobromae*, another wound parasite of bananas, do reduce the green-life of fruit. No data is quoted however. Since such an effect on green-life by *C. musae* could be of commercial importance in that, even though the disease may not be so severe as to disfigure the fruit, any reduction in green-life would contribute to the occurrence of 'mixed ripe', investigations were initiated at the Sandy Trout Food Preservation Research Laboratory to determine whether such an effect could be brought about by this organism.

In the investigations, three trials were conducted using Giant Cavendish bananas obtained locally.

Trial 1

Fifteen bunches were chosen, judged by the degree of filling of the fingers to be at different stages of maturation, that is, having different green-lives. On the day of harvest,

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fruit from two adjacent hands of each bunch were randomly distributed amongst six treatments, providing six fruit per treatment.

In each treatment fruit were dipped for 10-15 seconds in the following solutions:

Treatment 1	:	400 p.p.m. thiabendazole (TBZ)
Treatment 2	:	water
Treatment 3	:	<i>C. musae</i> spore suspension, 520 spores/ml
Treatment 4	:	" " " " 5200 spores/ml
Treatment 5	:	" " " " 52,000 spores/ml
Treatment 6	:	" " " " 520,000 spores/ml

The thiabendazole treatment was included to prevent the development of infection from natural spore loads, thus providing a control treatment in which no disease would develop (Scott and Roberts 1967). All solutions contained a small quantity of 'Agral 60', a commercial wetting agent. After dipping, fruit were held in an especially designed cabinet which was ventilated with humidified fresh air at a rate in excess of 100 ml/min/fruit. The cabinet was temperature controlled and was maintained at 20°C. Green-life was measured as the time that elapsed from harvest until the first detectable change in skin colour occurred.

In almost all instances, disease development commenced only at the proximal end of the fingers where they had been damaged by dehanding. To determine whether the rate of development of the disease was related to the level of inoculum used or to the stage of maturation of the fruit, the distance along the finger that rotting had progressed by the sixth day after dipping, was measured.

Trial 2

Fruit from one bunch of bananas were randomly divided between two treatments:-

Treatment 1	:	Fruit dipped in 1600 p.p.m. TBZ
Treatment 2	:	Fruit dipped in a <i>C. musae</i> spore suspension containing 42,000 spores/ml

The level of TBZ was increased in an attempt to overcome the small amount of disease development that occurred in the earlier trial. Both treatments again included a small quantity of 'Agral 60'.

Five fruit per treatment were then held in individual containers at 20°C and ventilated with humidified air. The respiration rates of these fruit were monitored daily using an infra-red gas analyser. The data obtained with infected fruit necessarily reflected the carbon dioxide output of the fungus also. Since the contribution from this source was only small and could not mask the onset of the respiratory climacteric of the fruit, the data will still be referred to simply as respiratory data. The remainder of the fruit were held in the cabinet described earlier. At 0, 4, 6, 11 and 13 days after dipping, ethylene production rates were determined on each of five fruit from each treatment. These fruit were then placed back in the cabinet and observed for a further 4 days. If a fruit showed colour and firmness changes during this period, it was assumed that it had entered the respiratory climacteric by the time its ethylene production rate was determined (Peacock 1966) and hence that determination was discarded.

This trial was repeated, the following alterations to procedures being made:

- (a) control fruit were treated with 800 p.p.m. of benomyl instead of TBZ in an attempt to reduce infection still further
- (b) the spore suspension contained 1,650,000 spores/ml, and
- (c) ethylene determinations were made at 0, 4, 6, 10, 12, and 14 days after dipping.

Trial 3

Cultures of *C. musae* were grown in potato dextrose broth. The media (10 ml) was inoculated with one drop of a spore suspension and incubated as a shake culture in a constant temperature water bath (25-26°C). Sixteen cultures were prepared at a time and incubated for 3 and 7 days. At the end of this period, culture vessels were flushed with ethylene free air, sealed with a rubber septum for periods of 3 to 4 hours at 20°C. The ethylene content of the air within the flasks was then determined gas chromatographically.

Uninoculated broth was also incubated as a check that, under the conditions of incubation, ethylene was not produced by some chemical reaction within the media.

Dry weight of fungus in the culture vessels was determined, the fungus being filtered off and thoroughly washed before vacuum drying at 75°C.

Results

Trial 1

A portion of the green-life data and the corresponding disease development rates obtained in this trial are shown in Table 1. At all inoculum levels used, green-lives of fruit were reduced below that of the controls (TBZ treated), the amount lost being dependent on the level of inoculum (Table 1). All differences are highly significant ($p < 0.01$).

Regression analysis shows that there is a highly significant relationship between the amount of green-life lost and the green-life fruit had at harvest (treatment 1), that is their stage of maturation. Data was significant ($p < 0.01$) for all treatments except treatment 2.

The rate of disease development was found to vary with the level of inoculum used to initiate infection (Table 1), differences between all treatments being significant ($p < 0.05$). Also regression analysis showed that the rate of disease development varied inversely with the green-life fruit had at harvest. Data was significant for treatments 4 ($p < 0.05$), 5 and 6 ($p < 0.01$) but not for the remainder, probably only due to the experimental error involved in measuring the very small extents to which the disease developed in these treatments.

Trial 2

Respiratory rates and ethylene production rates are shown in Table 2. For simplicity, only the respiration rates measured at the times ethylene production rates were determined, are shown. As stated earlier however, respiration rates were monitored daily. Infection was found to significantly increase both respiratory rate ($p < 0.05$) and ethylene production rate ($p < 0.01$). Fruit remained preclimacteric throughout the period over which ethylene production rates were determined.

Trial 3

Ethylene was identified as a component of the air samples by comparison of retention time with that for pure ethylene and by demonstrating that the suspect component could be absorbed by bromine water. An artificial gas mixture was used to ensure that ethylene and ethane were clearly separated under the conditions of chromatography, thus avoiding any possible confusion between these two substances.

TABLE 1

Changes in green-life in relation to anthracnose development. For ease of reference, green-life data is expressed both as mean green-life (days) and mean green-life lost (days). Anthracnose development is expressed in mm of rotted tissue 6 days after treatment.

The table shows only a portion of actual data.

Sample No.	M1	M4	M8	M12	M15
Treatment 1 Mean green-life	9.5	11.7	13.5	17.0	23.2
Anthracnose development	0.3	0.0	0.0	0.1	0.0
Treatment 2 Mean green-life	7.0	9.8	12.5	14.0	22.0
Mean green-life lost	2.5	1.9	1.0	3.0	1.2
Anthracnose development	4.0	0.3	0.5	1.6	0.1
Treatment 3 Mean green-life	7.3	7.8	11.0	13.3	16.3
Mean green-life lost	2.2	3.9	2.5	3.7	6.9
Anthracnose development	1.3	2.2	0.9	0.8	0.2
Treatment 4 Mean green-life	6.5	6.2	7.8	8.8	13.2
Mean green-life lost	3.0	5.5	5.7	8.2	10.0
Anthracnose development	9.5	6.8	3.9	6.7	0.5
Treatment 5 Mean green-life	6.0	6.0	7.0	7.5	7.2
Mean green-life lost	3.5	5.7	6.5	9.5	15.9
Anthracnose development	11.5	11.7	4.5	7.2	3.0
Treatment 6 Mean green-life	4.8	5.3	6.3	6.7	8.2
Mean green-life lost	4.7	6.4	7.2	10.3	15.0
Anthracnose development	16.0	17.5	12.8	19.5	7.8

TABLE 2

Effect of *Colletotrichum musae* infection on the ethylene production rate (ul/kg/hr) and respiration rate (mg/kg/hr) of bananas.

Time elapsed since inoculation (days)		0	4	6	11	13	
Replicate 1 Treatment 1 (control)							
Mean ethylene production rate		0.024	0.009	0.009	0.014	0.019	
Mean respiration rate		24.9	25.0	25.5	31.3	32.1	
Treatment 2 (Infected)							
Mean ethylene production rate		0.030	0.041	0.041	0.042	0.030	
Mean respiration rate		26.0	27.6	31.8	39.5	44.0	
Time elapsed since inoculation (days)		0	4	6	10	12	14
Replicate 2 Treatment 1 (control)							
Mean ethylene production rate		0.018	0.011	0.009	0.008	0.011	0.013
Mean respiration rate	-	23.7	29.6	20.8	24.0	24.7	
Treatment 2 (Infected)							
Mean ethylene production rate		0.016	0.092	0.059	0.099	0.053	0.043
Mean respiration rate	-	34.5	45.4	33.9	36.4	38.6	

TABLE 3

Ethylene production rates (ul/kg/hr) in relation to dry weight of fungus (gms.) after 3 and 7 days of incubation

Three days incubation		Seven days incubation	
Dry wt fungus	Ethylene production rate	Dry wt fungus	Ethylene production rate
0.0258	27.6	0.0561	2.2
0.0279	21.6	0.0563	0.5
0.0280	27.0	0.0571	1.0
0.0291	38.0	0.0574	1.1
0.0296	25.9	0.0579	0.9
0.0302	18.7	0.0619	0.9
0.0305	25.1	0.0631	1.3
0.0307	17.3	0.0647	0.0
0.0327	23.6	0.0649	0.3
0.0330	12.4	0.0654	0.3
0.0353	23.2	0.0664	0.0
0.0363	8.3	0.0697	0.0
0.0376	8.7	0.0698	0.8
0.0406	11.6	0.0706	0.0
0.0418	3.0	0.0743	0.0
0.0448	8.2	-	-
Mean 0.0334	18.8	0.0637	0.6

Dry weights of fungus and ethylene production rates obtained after both 3 and 7 days incubation are shown in Table 3. The ethylene production rates after 3 days incubation were significantly higher ($p < 0.001$) than after 7 days incubation, indicating that production rate probably varies with the stage of growth as was found for *Penicillium digitatum* (Phan - Chon - Ton 1957). Further examination of production rates within this table revealed that there was a significant negative correlation between the measured production rates and the dry weights of fungus in both the three-day (correlation coefficient 0.797, $p < 0.001$) and the seven-day (correlation coefficient 0.688, $p < 0.01$) samples. This is probably further evidence that ethylene production rate is a function of the stage of growth of the fungus.

Discussion

The results obtained clearly show that *C. musae* infection reduces the green-life of bananas. That the amount lost varied with the level of inoculum used and the stage of maturation of the fruit (green-life when TBZ treated) is undoubtedly due to the variation in disease development that occurred in relation to these two parameters (Table 1).

Increasing disease development with increasing spore loads is not a result to be unexpected, however the variation of disease development with stage of maturation is of interest. The existence of a natural antifungal agent in the skin of green bananas has been reported (Simmonds 1963), several compounds having such activity being recently identified (Mulvena *et al.* 1969). The latter authors have shown that under south Queensland conditions the antifungal activity of the skin varies during the year, being at a maximum during the winter months. It has also been shown to decrease as fruit ripen. The former variation is possibly a major cause of the low incidence of anthracnose during the winter period (Simmonds and Mitchell 1940). The disappearance of these substances as fruit ripen may also explain the development of latent infections. It is considered likely that the fact disease development was found to vary with the stage of maturation of the fruit (Table 1), probably reflects changes in the concentration of these substances, which occur even before ripening commences.

The observed increase in ethylene production rate from infected fruit is apparently due to the ethylene output of the fungus itself combined with an increased output from the fruit, the metabolism of which would be stimulated by the fungal ethylene. Since some evidence has been presented that the

ethylene produced by a fruit throughout the preclimacteric period is functional in determining when the climacteric rise will commence (Peacock 1971), the increased production of ethylene by diseased fruit would appear to be the cause of the demonstrated loss in green-life.

Infected fruit showed increased respiratory activity (Table 2). This is a characteristic response of plant material to the attack of a parasite (Uritani and Akazawa 1959). In this instance, it is undoubtedly partly due to the respiratory output of the fungus itself, but also may be a result of the fruit's respiratory rate being stimulated by the increased ethylene production rate (Hansen 1967).

The results obtained in this investigation have thus demonstrated that, as well as causing wastage by disfiguring fruit, anthracnose may also cause losses through premature ripening. It must be stressed that in these trials up to a 50 per cent loss in green-life with the most mature fruit was obtained within 4 to 5 days of inoculation, and this was obtained at a temperature of 20°C. The optimum temperature for the growth of *C. musae* is about 30°C., which is not an uncommon temperature for fruit to experience within normal commercial practice. Hence in commercial practice, disease could be expected to develop much faster and thus produce even greater reductions in green-life than obtained in these trials. In view of these facts it is proposed that anthracnose of bananas, produced by non-latent wound infections, is probably a major factor contributing to the occurrence of the 'mixed ripe' problem of the Queensland banana industry.

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Discussion

Green-life is of great practical importance as all bananas are required to be transported in a hard green condition to the point where controlled ripening is undertaken.

Fungal development did occur on inoculated bananas within 24 hours and as ethylene production from moulds was greater in the earlier stages of fungal growth ripening of sound bananas was hastened by the presence of moulds on adjacent fruit.

SYMPOSIUM I. RESEARCH, DEVELOPMENT AND EXTENSION

HORTICULTURE, THE LAGGARD

E.G. Hall^{*}

The purpose of this brief symposium is to consider whether research, extension and development in Australia are efficiently serving the fruit and vegetable industries so that they can meet the mounting difficulties in profitably disposing of their crops and at the same time increase consumer satisfaction.

The Problem

I am concerned at the generally poor standard of technology in marketing perishable produce - along the whole chain from orchard, garden and field to the table.

Why is there so much resistance to and delays in the application of technical advice well founded on research? Is it because of ignorance, are we failing in our extension activities, is it conservatism, actual reluctance to change, or is it a real doubt about the economic value of new technology, fear of higher costs without better returns?

An example is the failure of the banana industry to accept packing in sealed polyethylene bags which has been well proven. Despite the obvious and industry proven benefits, treating bananas with TBZ or benomyl to control fruit rots is not practised by many growers and many who do are careless and only partly successful. Another example is failure to use ethylene gas to ripen honeydew melons. Perhaps people are afraid that their lack of knowledge will not enable them to take the extra care and attention that the extra rewards from improved technology so often require. Lack of extra care is a factor in poor performance in much of the C.A. storage of apples, for example. Is there a crisis of confidence, a lack of confidence in their ability to survive in an increasingly technological and competitive world?

The attitude to technical change is so often negative, reasons are advanced why it would not work or could not be used, rarely is the approach, well how can we use this? Even when new technology is used it is unfortunately often in a slipshod manner which denies full benefit.

The standard of management is unfortunately generally low, particularly in comparison with that in the marketing of manufactured goods, and there is wide ignorance by growers, plant

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managers and operators of the basic nature of the living plant material on which their livelihood depends.

I recall a recent address to the Sydney University Agricultural Graduates Association by H.D. Black, Chancellor of that University. Taking as his subject "The Winds of Change in Ideas and Practices" he said "Ignorance is not, and never was, bliss.---. The world pays a heavy price for laggard minds, and for the lazy use of entrenched practices. Industries in which conservatism reigns in part or whole are industries wherein a few pioneers shine out amid a mass of people who think in the old conceptual way, and apply knowledge which has been proven in the past but is now superseded. Persons are bundles of ideas and experience; they need a commerce of ideas in free exchange. It is urgent in all disciplines throughout Australia to create institutions for acquirement, storing and effective transfer of new ideas. The computer helps. But whom does it help? It helps only those who continue to ask questions and who scrutinize their own practices objectively".

Our job, and I am speaking widely collectively here, is to make sure that we are doing research on the right things and, most importantly, bridging the gap between research and practice through extension and assisted development. This will require specialist extension officers who do not yet exist in this country and active cooperation between various disciplines. Cooperation with economists in assessing the value of new or improved technology arising from research is urgent because of the now narrow gap between costs and returns for many products of horticulture.

Further, any research worker supported by public funds cannot in conscience isolate himself from the realities of costs and returns. Applied research - research to meet a need - is important and necessary and must be as well rewarded as detailed basic findings which have no immediate application. Research in State Departments of Agriculture is mainly applied but both CSIRO and the Universities must give practical recognition to technology and be actively concerned with "research to meet a need". This is recognized by the Chairman of CSIRO, Dr J.R. Price. In discussing science policy (Coresearch no. 152, 1971) he said:

"We are concerned as much, or more, with the application of science as we are with the advancement of knowledge. But, in accepting this link, I think it worth pointing out that, while science and technology are inextricably involved with one another, scientists and technologists are not. --- Scientists have little conception of what is required to translate a scientific discovery, pure or applied, into a technological

advance, an economically viable process or product."

I believe that CSIRO must take a more active role in the application of science and that this would not be an infringement of State rights.

More than ever we must continually be aware that we serve not only the producer but also the consumer of perishable produce.

Fred Heringer (*Hort. Science* 6: 469, 1971) put this well. "Delivery of eating satisfactions to consumers involves a whole bag of disciplines from genetics through production, harvesting, storage and marketing to a real awareness of consumer behaviour. I pose, then, that the new awareness of the consumer and the emergence of ecological challenges call for some new approaches to research".

Not only must we constantly try to improve the quality of the consumer product but the consumer must know what we are doing. Science and research have to be promoted and sold like breakfast cereals and soap. I believe that we have been falling down on the job of improving, even maintaining, eating quality, particularly flavour, for the consumer. Fruit is a luxury, it is not an essential food, but essential to fruit is the quality of consumer enjoyment, without it the fruit industry has an uncertain future.

In 1970 the Australian Institute of Agricultural Science held a symposium in Sydney on the "Self-perpetuating Inertia in Australian Agriculture".

We must not be a party to that inertia. In a challenging address to that symposium entitled "Marketing - a necessary ingredient of change" Sir Walter Scott said, *inter alia*,:

"First, nobody is ever really in business until they have a market.

Secondly, that country, that company, that product, is doomed to ultimate failure to the extent that its philosophy is product-oriented instead of marketing-oriented.

Thirdly, the onus of getting the product to the right buyer at the right time and for the right price is on the seller, not the buyer.

Today, the buyer in many cases has a lot of choices and we must remember this".

These principles of marketing are not well recognized by the fruit and vegetable industries. I see it as an important part of our job to help our industries to accept them and to operate by them.

Marketing orientation is doubly important in the research and extension we are considering because both the needs of the producer and of the consumer - the buyer of the produce - must be considered.

It is almost everywhere apparent that, particularly in their marketing, the fruit and vegetable industries have been unable to realize the potential of the wide variety of technological developments resulting from research, both Australian and overseas, to overcome or better handle marketing (and production) problems. The missing factor is more often than not adequately planned management. Better management is the modern key to survival. It does not just happen, it must be planned. We must help with that planning in horticultural marketing.

The Cure

Firstly: With our limited resources of personnel and finance research must be more integrated and coordinated. For more effective research and development we need a national body like the Marketing Facilities Division of the Agricultural Research Service of the U.S. Department of Agriculture. It is actively concerned with improving marketing technology by the application of research findings and employs horticulturalists, plant physiologists, biochemists, engineers and economists and carries out many investigations in cooperation with universities and industry. If a national body is politically impracticable in Australia then similar integration and cooperation should be developed at the State level. Basically we must be able to tell the grower, the packer, the cool store operator or the shipper that a new idea will work and will be profitable in reduced costs or better quality before we can expect it to be adopted.

Secondly: We must become actively involved in education not only of management but also of operatives, not only through special extension officers, not yet appointed, but also directly. Research officers must not be aloof from the industry they should be serving. It must not be forgotten that there is a valuable feed back by rubbing shoulders with industry. This will require more and better extension publications, more widely distributed, extension schools and symposia and also basic management training, which would benefit most of us too as we also need good management in our own operations.

There should be more in-service training of research and extension people through refresher and specialist courses. Extension workers need more support from researchers and should be actively associated with applied research and development.

To help bridge the gap between research and industry specialist post-harvest horticultural extension officers should be appointed by each State Department of Agriculture.

Thirdly: Even though they are less wealthy than other primary industries the fruit and vegetable industries must make significant financial contributions to the cost of research, when they will have a right to expect meaningful results from that research.

If they do not do this their share of the total research effort, already small, will probably decrease. These contributions could be most effectively organized through research associations financed by government controlled levies on production. Such associations could eventually employ research and development staff of their own and so achieve the goal of these industries doing a significant proportion of the research, extension and development themselves. This would be more easily achieved with an organized industry, at present the fragmentation of the fruit and vegetable industries is perhaps their greatest handicap in today's highly competitive world of marketing.

I am not necessarily advocating marketing boards although they can work well as instanced by the success of the Deciduous Fruit Board and the Citrus Export Control Board in South Africa, and the Citrus Marketing Board in Israel which are very responsive to research. I believe that the Australian Apple and Pear Board should have full power to market the crop and that it should employ highly skilled people to carry out its functions. Cooperatives, if they are large enough and are run by professionals, can succeed. Marketing is a job for professionals not amateurs, growers are usually amateurs in marketing. The Australian citrus industry, at least that in the Murray and Murrumbidgee basins, and the NSW banana industry are in dire need of a strong overall marketing organization which has the power to take full advantage of new technology to provide consumers with what they want. If the Australian Constitution is a barrier to effective control of production and marketing to strengthen their competitive position then it is high time that the Constitution was changed; as is now accepted, it is time for change.

If the fruit and vegetable industries cannot properly control their own marketing, and the evidence that they can is not encouraging, then Government should take over as it has done most successfully in the Israel citrus industry. It might be called socialism but it would be sound practical common sense and in the interests of producer and consumer and of all taxpayers.

Finally: Increasingly, technical advice and assistance is being provided by the service industries. Some of this is very good, for example, that provided by the A.P.M. Co, as an

essential part of their campaign to sell cartons to the fruit industry, led the way in improving handling and packaging. In the future, can we leave technical services to industry, and to management consultants in the city? I believe we cannot, the family farm will be the mainstay of horticulture for a long time and sociologically this is a desirable state of affairs to maintain.

RESEARCH, EXTENSION AND DEVELOPMENT IN THE MARKETING SYSTEM

W.J. Greenhalgh^{*}

I would like to speak of research, extension and development on the grand scale, to consider the system rather than its components. I could consider ways in which the bushel box might be improved but I would prefer to question whether we have, in fact, any further need of the bushel box!

We tend to conceive of the fruit and vegetable industries as comprising two systems; the production system and the marketing system. Like other systems, we can repair, replace or refine the components with marginal advantage to the efficiency as a whole but eventually there comes the time to build an entirely new system. As my colleague would say, polishing the car may be a rewarding activity but does it provide for a better means of transport?

Production horticulture is going through an interesting stage of system replacement. Mechanization of operations, especially of harvesting, is forcing us to devise new systems and not merely to modify old ones. Research workers are questioning accepted dogma such as the planting of trees at 22' spacings; the vase shaped form of tree training; the necessity for an indeterminate growth habit of tomato plants; the tapering form of carrot roots, and whether there really is any need for watermelons to have seeds. Alternative model systems are being created. These models provide varied architectural forms to allow for the most effective use of solar radiation, air, water and soil space allotted to the plant; and specify mechanical properties appropriate to the operations to be performed on them by machines.

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This model building activity takes various forms; some use imaginative new pruning methods in the field; some devise the new crop ideotype and then set about breeding it; some substitute simple annual species for the more complex perennial plant system, and some use computer simulation to derive a mathematical model and an array of theoretical alternatives. It is true that bizarre results do emerge. One reads of an apple meadow with trees mown off every second year; or of the conversion of the grape into a dried fruit before it is harvested; of the photosynthetic capacity of a theoretical canopy where the leaves are always perpendicular to the incident radiation, or of yield density relationships worked out for pruned soybeans. The essential feature common to all these approaches to research and development in production horticulture is a desire to provide alternative systems rather than to patch up the existing traditional model.

What do we find in that part of the horticultural industry we call the marketing system? Where are the model builders, the system analysts, the imaginative or creative workers who could point the way to new horizons? I fear the hand of custom and tradition lies heavily on the marketing of horticultural products.

To the consumer, the marketing system is at least as important as the production system for both contribute about equally to the final cost of the product. In terms of the value added concept, it would be appropriate to allocate our resources to each component of the system in proportion to the contribution that component makes to the ultimate value of the product. If we were to examine the distribution of research and development effort in relation to value added I believe we would find that there is a need for more attention to be paid to the wholesale and retail trading components. It is perhaps significant that in the plans for expenditure of \$14 million on the new City of Sydney Markets, no provision was made for a research and development section. Any other comparable system of equivalent cost would have provided such facilities in its own interests or would have had the facilities provided by the government in the public interest.

I suggest we might begin by constructing a model for the flow of fresh fruit and vegetables from areas of production to areas of consumption at the national level. This ought to be done for the seasonal pattern of flow of each major commodity projected forward for the remainder of this century. This basic information is essential for effective research on the logistics of developing suitable container and transport systems. With this information it should be possible to devise a limited

number of modules capable of continuous use with a variety of kinds of produce. I am not convinced that the disposable carton in its many shapes, sizes and colours is the ultimate answer to the packaging problem. I would go further and say that the bushel carton is a very significant part of our present problem; it is too big for the average consumer to buy and too small for effective mechanical handling and stowage. If a standardized module could be devised, would it be a bushel box, a pallet based crate, or a fully enclosed bulk container with built-in temperature and atmosphere controls?

The number, variety and location of retail outlets in the community structure could well be investigated. I believe that town-planners would be receptive to guidance on the special needs of the fresh fruit and vegetable trade concerning number, size, location and special services required by the retail outlets. Surely this would be preferable to the setting aside in community centres of shop units for general trade, e.g. dry-cleaning, hair-dressing or fruit shop? In a 0.8 mile stretch of Parramatta Road there are 16 single fronted green-grocer shops. These shops face six lanes of slowly moving traffic on a road where standing or parking of vehicles is prohibited. Thermal and air pollution on a calm day is of a high order but nobody seems to have been interested to measure fruit pulp temperatures or ethylene levels in such shops.

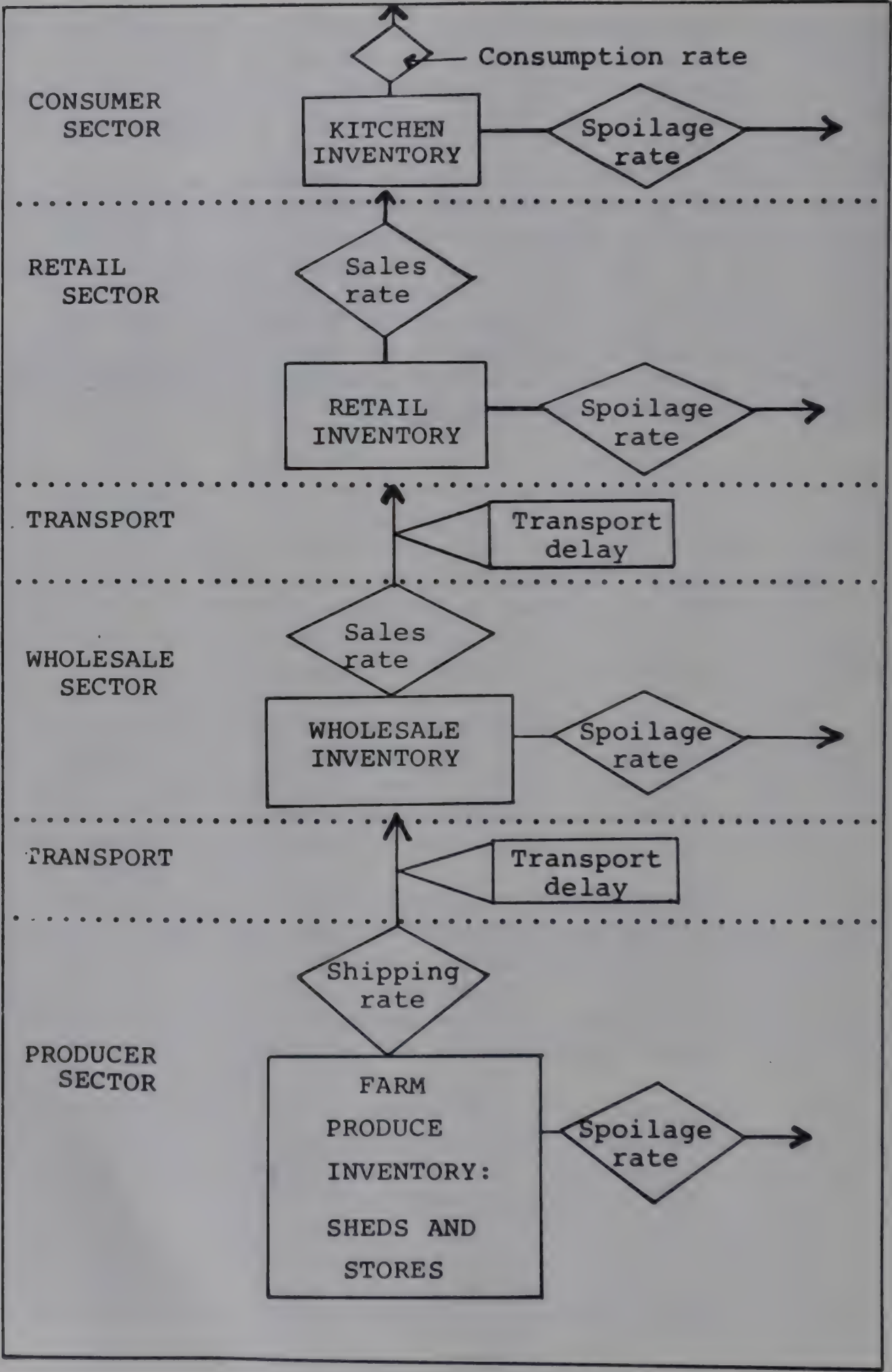
Model retail outlets should be designed. I use here the word 'model' in the system analysis sense. The model should integrate physiological criteria and limitations of each item of produce with its known characteristics as merchandise. Models should be designed for both supermarket and the traditional retail outlets.

It may not be out of the question to consider the models of storage of fruit and vegetables in the home and kitchen. It may well be that the 'crisper' in the domestic refrigerator represents the ultimate in this regard. I doubt it, and I believe that kitchen designers would be quick to incorporate features of this kind once the principles of design and operation were enunciated.

These considerations may smack of a brave new world. However, I believe that research and development should mould the new world rather than repair the old. The way to do this is to provide an array of alternative systems so that society may choose that which it prefers. The biologist, the engineer, the economist and the sociologist should provide information on the constraints to be applied to the system; this would be positive R. and D. What I fear will happen is that marketing

enterprises will provide the system and the fresh fruit and vegetable trade will be required to conform to that system. When this happens it is the consumer who suffers and the biologist and the engineer who are committed to an endless task of corrective R. and D.

Some idea of why increased storage capability or improved wastage control at the production end of the system may have little impact at the retailer or consumer level may be seen on consideration of the dynamics of the system presented schematically on page 262. The whole is greater than the sum of the component parts: for too long now the storage of fruit and vegetables has been a component of the whole marketing system. Effective R. and D. depends on who provides the specifications on which the total system is designed.



THE PLACE OF EXTENSION IN POST-HARVEST HANDLING, PRESENTATION AND STORAGE OF FRUIT AND VEGETABLES

R.T.J. Webber^{*}

In the past research and extension officers working in government departments have been mainly concerned with increasing farm productivity (yield per acre) and net returns by means of improved technology and better farm management techniques. Although these objectives will continue to be important in keeping the farmer financially viable, it is becoming increasingly apparent that much greater emphasis will need to be placed on research and extension, which help to sell farm produce at a price acceptable both to the farmer and the consumer.

The sequence of events involved in getting a case of fruit or vegetables to the consumer is a very complex SYSTEM or marketing chain, involving many groups of people, each with a separate but vital role to play.

The SYSTEM can only work efficiently and smoothly and meet each group's requirements if there is good liaison, understanding and cooperation at all levels and the SYSTEM can only survive on highly competitive markets if each component or group in the SYSTEM is prepared to keep abreast of the latest scientific developments and adopt those practices which promise to be economically beneficial and/or improve the marketability of the product.

Who Controls the SYSTEM?:

It seems logical that the Industry Organization is in the best position to coordinate, supervise and guide each component or group in the SYSTEM or marketing chain, in its endeavour to get a high quality product to the consumer.

Role of the Field Extension Officer (so called General Practitioner):

The extension officer working with growers in the field has a restricted but nevertheless important part to play in the SYSTEM. His major functions are:-

- * to liaise with research staff and industry and to see that research is relevant and important

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- * to adapt new findings of research into the grower's system of management
- * to encourage the grower, by educational procedures, to see the importance of quality and the part that he plays in the whole SYSTEM of marketing a high quality product
- * to define and demonstrate how to produce high quality fruit and vegetables, how to harvest them at the correct stage of maturity to meet specific market requirements and how to handle and deliver the produce to the packer or processor in a good condition

Many of our recent field days have highlighted the importance of fruit and vegetable quality and have given special emphasis to the following:-

- * external appearance - freedom from unsightly blemish, good shape, size and colour for the particular variety, freedom from pest and disease and generally good outward condition and appearance
- * internal quality - sugar-acid balance (palatability), percentage of total solids, juice content, internal characteristics such as colour of flesh, degree of seediness, internal disorders, rind or skin thickness, etc.
- * keeping quality or storage life - attention has been given to the importance of the stage of maturity at harvest (correct picking time), balanced nutrition, use of growth regulators to improve quality and storage life, crop regulation (size of crop), care in handling, storage conditions (including temperature and humidity) from time of harvesting to selling and the time lapse between picking and post-harvest fungicidal treatments.

It is essential that the marketing SYSTEM commence with a high quality product, which, if given the right handling and storage conditions, can reach the consumer in an acceptable condition. A poor product originating from the grower has no hope of improving as it moves through the SYSTEM to the consumer.

Role of the Post-harvest Specialist:

Once the fruit reaches the processor or packer, and enters the marketing channels there is little that the field extension

officer (G.P.) can do - he has neither the time nor the specialized knowledge required. This is where the Post-harvest Specialist (applied or adaptive researcher cum extension officer) fits in.

Already a number of post-harvest extension specialists have been appointed in the U.S.A. to work with people involved in the post-harvest handling of fruit and vegetables. Some of these officers feel that their job starts with the fruit on the tree and carries right through to the market.

I consider that similar developments are inevitable in Australia even if the duties and degree of specialization of the post-harvest specialist are somewhat different. Personally I would like to see the duties of a post-harvest specialist be along the following lines:-

- (1) applied or adaptive research - 35% of his time - this would give him the necessary expertise and credibility with the people he is dealing with.
- (2) personal contact extension - 25%. This would include visits to processors, packers, markets, answering office and telephone queries, etc.
- (3) group contact extension - 15%. This would cover involvement in field days, seminars, schools, group discussions, etc.
- (4) mass media - 10%. This would include preparation of newsletter items and leaflets, radio talks, etc.
- (5) administration, correspondence, attendance at conferences and also personal improvement programmes - 15%.

It would be important for the Post-harvest Specialists to confine themselves to one or two crops. Compare this with the present position in Australia where often one post-harvest researcher cum extension officer deals with almost all crops.

The post-harvest specialist would become the resource person in most post-harvest issues for a particular industry. He would spend a considerable amount of his time reviewing the literature, selecting, adapting and integrating new ideas to suit specific post-harvest problems and new marketing situations. He would need to develop and maintain close liaison with all groups in the marketing SYSTEM from the grower to the consumer, ensuring a good two way flow of ideas and information.

It would be essential for him to be very conversant with State and Commonwealth Acts and Regulations, and be involved in their drafting and modification. He would be in an ideal position to

promote and disseminate good ideas and practices originating within the SYSTEM and to develop good communications through personal contact and the use of industry newsletters.

Some Differences Between the Field Extension Officer (G.P.) and Post-harvest Specialist:

- * the post-harvest specialist would be dealing with fewer people, each working in a specialized field
- * generally speaking, he would be dealing with people who had a better education
- * his clients would be under greater pressure to change and adopt new practices. Pressures would be coming from the grower for a better 'outturn' and price for his fruit; marketing and sales people would be continually pressing for continuity of supply of a good selling product and the inspection services would be demanding certain quality standards
- * the post-harvest specialist would also be concerned with more complex changes in equipment and practices, which would require much more personal involvement and advice if they were to be carried through to the adoption stage. Extension research has shown that the more complex the innovation or change, the slower the rate of adoption.

The Modern Approach to Extension:

A brief discussion of the modern approach to extension could be of value in considering the role of post-harvest specialists (with a strong extension function), in selecting the right type of person for the position and in deciding the type of extension training he may need.

Extension today is largely directed at helping people to help themselves. It is essentially an educational process aimed at encouraging and assisting people to clearly define their objectives, to become technically more competent, to improve their efficiency by developing management skills and to make them better decision makers. The good extension worker frequently acts as a catalyst in stimulating or motivating people to change and adopt new practices.

He must, of course, closely liaise with researchers, not only for the purpose of getting information, but to ensure that the research work carried out is relevant and of greatest economic importance to the industry. Needless to say, he must be

technically competent in order to gain the necessary respect and credibility within the industry.

In selecting a person for the position of post-harvest specialist and in training him to carry out the duties efficiently, thought would need to be given the following:-

- * good technical training and experience in applied or adaptive research work
- * considerable experience and formal training in extension work and methodology
- * personal qualities which would enable him to effectively liaise with all sections in the SYSTEM from the grower to the consumer.

SYMPOSIUM DISCUSSION

The importance of extension as a profession and the need for recognition of the principle of equal status and salary for extension workers and research workers were emphasized. Good extension needs highly qualified people, the modern extension worker must become socially and psychologically involved with people, assess situations, decide priorities and influence both research and practice.

It will be difficult to raise the status of extension workers because the value of their work has to be assessed differently from that of their colleagues in research.

SYMPOSIUM II. EXPORT DEVELOPMENT

EXPORT DEVELOPMENT

C. Flynn^{*}

I propose to discuss the export of fresh fruit and vegetables to Europe and some problems of outturn associated with this trade.

Europe remains the principal market for apples and pears exported from Australia. To place this in perspective, over 80%

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of the 5,140,000 bushels of apples and 65% of the 1,820,000 bushels of pears exported in the statistical year 1971/72 went to Europe. Britain remained at the top of the list of destinations.

Modern reefer vessels built to transport unitised packages of fruit and operated by a Swedish company can now complete the voyage from Tasmania to a Baltic port in 28 days. The refrigerated shipping container is an ideal vehicle for fruit transport and container ships can average 26-28 days from ports in eastern Australia and 21-22 days from Fremantle to Europe. The introduction of more modern and faster ships since the closure of the Suez Canal, and the increase in air cargo capacity since the advent of the jumbo jet, have led to a re-appraisal by some European importers of Australia as a source of out-of-season fruits and vegetables.

Statistics issued by the Department of Primary Industry, the Commonwealth Department that administers the Exports (Fresh Fruit) and Exports (Fresh Vegetables) Regulations, show an increase in exports of citrus fruits consigned to Europe in 1970 and again in 1971. There are some good niches in that market between July and November for large-sized navels and for mandarins, Valencias, grapefruit and lemons. Grapes, stone fruits, melons, berries and many vegetables can meet a demand at certain times of the year. Some commercial and trial token consignments have been sent in recent years.

The pattern of trading in these perishables is changing from the traditional auction/wholesale market to distributor, retailer and then to consumer. Increasing quantities are imported, stored, pre-packaged and then distributed to supermarket-type food chain shops operated by firms such as Sainsburys and Marks & Spencers in Britain, Albert Heijn in the Netherlands and the large cooperatives in Scandinavia. The consumer is accustomed now to an around-the-year availability of a wide range of high quality, attractively presented fruits and vegetables held under optimum storage conditions prior to sale. The rising living standards in some European countries have increased the demand for what were once luxuries. Concentrations of some non-indigenous ethnic groups in Britain has led to a demand for more exotic tropical fruits and vegetables.

Australia enjoys some advantages (shared by some other suppliers) and certain handicaps as a source of supply to the European market. Our climate and seasons complement those of the northern hemisphere, our consumption tastes are similar, our transport from source of supply to market is reasonably good and we have the technology to overcome problems of

production, packaging and transport as these arise. On the other hand our geographic isolation from Europe is a disadvantage that results in high freight rates and our high labour and production costs, in what remain rather labour intensive industries, are competitive handicaps (e.g. compared with South Africa).

The European market, traditionally an outlet for our exportable surplus production of apples and pears, has recently started to show an interest in other fresh fruits and vegetables from Australia. It is ironical that this has coincided with a setback in the market demand for apples and, to a lesser extent, for pears. In 1970 and again in 1971 the supply of apples during April to July when exports from Australia are arriving on the major European markets, usually exceeded the demand. This has been brought about by advances in storage techniques which enable more northern hemisphere production to be carried over into the following summer and by increased production from South Africa. In spite of strenuous efforts by the industry in Australia to keep its costs under control by shipping in bulk bins and in unitised packages it seems probable that the quantities of apples shipped to Europe will continue to decline. There should remain a place for good quality apples and pears that outturn in sound condition and the market opportunities for citrus and for some other fruits and vegetables have yet to be fully exploited. This market deserves closer study in order to ascertain precisely what it wants.

I would like now to refer back to some problems of fruit transport and outturn that I saw during my term in England. The purchase by a European of an apple (or any other fruit) from Australia represents the last link in a long chain operation. It is ideally the result of selecting the correct variety to produce under favourable growing conditions, harvested at its correct stage of maturity, handled correctly prior to and after packaging, packed in such a way to ensure protection and sales appeal, transported under optimum carriage conditions and properly handled on arrival at its destination. Unsatisfactory outturns usually result from a neglect or breakdown of one of these factors.

The refrigerated shipping container can now give the shipper control of the conditions of storage and carriage of perishables from point of production and packaging to point of outturn in Europe. It has resulted in the elimination of bruising, damage to product and package, and the deterioration of fruit condition that can be seen at ports when conventionally stowed ships are discharged. It is an average of 10-14 days, and on occasions 20-21 days, before apples are sorted to importers mark and

cleared from non-insulated storage at some U.K. ports. During warm spells of weather this delay plays havoc with the condition of the fruit. In 1972 a system of direct delivery ex ships from Tasmania was attempted and met with commendable success in the United Kingdom.

In spite of the advances made in fruit storage and transport since the last Conference bitter pit remains the most serious disorder at outturn in our export fruit trade. Bitter pit results in considerable economic losses to the Australian industry in some seasons and some shipments of our premium export variety, the Granny Smith from Western Australia, outturned 20% of the fruit with pit lesions early in the 1970 season. This not only discounted those shipments but had a psychological 'fall-out' affect in exporters' minds concerning this and other pit-susceptible varieties from Australia for the remainder of the 1970 season. The cost to the industry has not been assessed though it was probably of the order of \$1.5 million that season.

The other progressive disorder, superficial scald, while not seen in as much fruit as was bitter pit, was a problem in Granny Smith from New South Wales and Victoria towards the end of the 1971 season when 90% of the fruit in some containers outturned scalded, although oil wraps had been used. It is unfortunate that acceptance by importing countries of both diphenylamine and ethoxyquin as post-harvest treatments of apples and pears is still far from consistent and widespread in Europe.

One still sees evidence of pre-shipment bruising and fungal breakdown in apples and pears from insect stings, mechanical damage and torn stem ends; however, more serious than these defects is mixed maturity at outturn which points to late packing and variations in pre-shipment handling practices by export growers. Mixed forward conditions sometimes associated with breakdown and low temperature ripening were particularly prevalent in the increased quantities of W.B.C. pears sent to Europe from Victoria in 1972. The lack of adequate dunnaging in containers tightly packed with cartons prevented the free circulation of cool air and contributed to the unsatisfactory outturns.

Most fruit from mainland States to Europe is now carried in refrigerated containers and problems at outturn can usually be traced to maturity at harvest or at time of shipment, to unsuitable packaging and to variations in the storage and carriage temperature of the fruit.

Exports of oranges to Europe increased from 123,000 bushels in 1970 to 285,000 in 1971. During the same period mandarin

exports to Europe went from 10,000 to 12,000 bushels. Wastage from blue mould and sour rot type of fungal breakdown was a problem in navel outturns in Rotterdam in August, 1970. Circumstantial evidence at outturn pointed to incorrect pre-shipment fungicidal treatments and to rind pitting from low temperatures as the probable causes of some of the trouble.

The following year there were losses of the order of 15% in the contents of some containers of mandarins. Puffy fruit was overpacked, compressed and blocked many ventilation holes in the cartons.

There were few problems in the small consignments of grapes exported to England in recent years. Shipments of onions outturned in sound condition but a maturity factor at shipment resulted in considerable sprouting in the 1972 shipment.

Plums shipped in containers outturned in London during the winter months of 1970 and again in 1971. As with fresh pineapples that were air freighted to London late in 1971, and outturned during cold weather when ambient temperatures can remain around freezing point for prolonged periods, these and other fruits outturning during the colder months require ripening on arrival.

Cherries, asparagus, strawberries and token quantities of pome and tropical fruits have been air freighted to England from Australia. To be successful, air freighted fruits require special packaging and handling and ideally, to avoid damage from careless handling at a number of transshipping points, a direct flight.

In conclusion, to come back to export development in an industry troubled by low prices and over-production, regular market studies by exporters are suggested. This should result in importers and distributors in Europe getting the varieties, sizes, maturity and some speciality packaging that they want, not necessarily what we in Australia think that market wants. There are market opportunities for our fresh fruits and vegetables in Europe, particularly if we concentrate on quality rather than quantity. If the industry can get both so much the better, but the priorities should be quality rather than quantity.

The European Economic Community and the imminent entry of Britain into the Community is popularly considered to be the cause of many of our present and potential problems associated with the marketing of pome fruit in Europe. In the short term British entry is not going to make things any easier. This is a problem, however, that has to be faced also by other southern hemisphere exporters to Europe. In recent years Germany,

Netherlands, Belgium and France have remained viable markets for southern hemisphere fruit.

The consumer tends to tire of overstored French Golden Delicious and the importers' lobby has some influence on European Economic Community policies. The anticipated rising living standards in Common Market countries will be reflected by an increase in consumer demand for fresh fruit and vegetables. This presents a challenge and should provide some opportunities for a positive thinking, progressive export industry in Australia to accept.

MARKET DEVELOPMENT - SOUTH EAST ASIA

F. Melville*

With the uncertainties and oversupply of the European markets, Asia becomes a potential alternative market for fruit exports from the southern hemisphere.

The value of imports of fruit into the South east Asian countries of Singapore-Malaysia, Indonesia, Hong Kong and Japan is approximately \$A300 million per annum. Australia's share would be little more than 1% of this and there are considerable difficulties in the way of significantly increasing it. Important criteria in assessing a market are firstly, the market's need of imports, secondly the supply position, and thirdly, special requirements pertaining to that market; and these aspects are dealt with in the following discussion.

SINGAPORE-MALAYSIA:

Singapore-Malaysia imports approximately \$60 million of fruit per annum, and has an established market for Australian produce; it also serves as a distribution point for a limited amount of fruit going to Indonesia.

At the present time there is a concerted campaign in Malaysia to foster the consumption of locally grown fruits by extolling their nutritive value. Legislation was also passed by the Malaysian Parliament in January, 1972, empowering the Government to double the duty on imported fruit from \$M448 to \$M896 per ton. This has not been implemented but will have serious

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consequences on costs if it is. The duty at present is 20¢ (Singapore) per lb and this would rise to 40¢ per lb. In view of Malaysia's reliance on imported fruits this imposition is difficult to understand, except as a move to thwart the Singapore Chinese importers. This possibility is supported by the threatened ban on the importation of Chinese fruit through Singapore, previously the normal route, as opposed to direct shipments to Malaysia.

Imports into Singapore

Singapore is a free port and therefore open to the world for the importation of fruit. Main suppliers are Australia, China, United States of America and Israel but imports of specific fruits also come from Formosa, Spain, New Zealand and Canada. Direct shipments from South Africa are not permitted but considerable quantities of citrus, grapes and some plums arrive by devious means from that country in boxes bearing no country of origin. Australia is the main supplier of apples, grapes and plums and second only to China in pears.

Apples. Australia traditionally supplies almost half the apple imports, about 300,000 bushels from Western Australia and about the same quantity from Tasmania.

For many years Singapore was essentially a green apple market but it is now showing a very definite preference for red varieties, particularly Delicious. Western Australian Cleos and Granny Smiths are well accepted on the first boats, but when the Queensland Delicious arrive in April followed by Tasmanian shipments, Granny Smiths are not wanted until the reds are starting to decline or are showing signs of over-storage, usually by July. This year Yates sold at higher prices than Granny Smiths due to a shortage of red varieties from Tasmania. Importers generally expressed preference for large apples but this is very much a matter of price levels. When the market prices are high there is a tendency to move to longer counts. In Singapore and Malaysia fruit is usually sold at so many pieces per dollar and this influences the thinking of the trade in terms of fruit size and counts. For instance, the general comment on the Scoresby carton is that it contains less weight than the standard tray packs. Probably what is meant is that in certain size ranges the Scoresby count is less than the standard tray pack and as the size differential is not detectable by eye, the retailer finds he has less pieces of fruit to sell at the same price in the Scoresby carton. There was also an expressed need for 216 count Granny Smiths to meet the requirements of the Malaysian trade. With the shorter journey and slightly cheaper freight Western Australia should be

working for a share of the current red apple trade, which would not necessarily be at the expense of Granny Smith shipments. Some consideration could be given to the early shipment of Jonathans but fruit size would need to be kept up. The order of preference of packages for Australian apples was stated as standard tray pack, cell pack and Scoresby tray pack.

China supplies at least as many apples, sometimes more, than Australia but shipments do not commence until September and are finished by the time the first Western Australian apples are shipped. The quality of the Chinese apples, which are mainly green and packed in cartons, is not good and prices obtained are only about half those for Australian fruit. It is interesting that some apples have also been shipped to Singapore from France and Hungary in recent years. If free passage via the Suez Canal was resumed this trade could increase considerably.

Pears. China dominates the pear market but does not clash with southern hemisphere fruit. Several other countries, including Japan and Korea, also ship pears to this market. The preference is for very large pears of the Packham type. Victorian Packhams are considered the best. The Singapore climate accelerates ripening and it is essential that all fruit arrive in a hard green condition.

Plums. Southern hemisphere suppliers are Western Australia and South Africa, with U.S.A. shipping limited quantities in September and October. Large size with good shelf-life and preferably red colour, are the characteristics sought. Santa Rosa seemed to be first choice among Australian fruit and Narrabeen second if colour was good. Wicksons were not favoured on account of immaturity in many instances and rapid ripening of any at all forward. Ruby Blood at times became bladdery and was viewed with caution. Beauty is popular on account of its earliness. A better variety in this early period would be very worthwhile. The Kelsey is the one green plum which has a very good name and is popular with the trade. South Africa is the only source of this variety in our season.

As with all fruit, the prime acceptance factor is cost and any change in packaging which increases the price is not favoured. Therefore smaller packages, such as are used by South Africa, would only be acceptable if they could be delivered on the same unit cost basis as half-bushel dumps.

Grapes. The United States is the largest supplier of grapes to the Singapore market, with Australia in second place. Shipments from Spain, although still considerable, have declined over recent years.

Western Australia and Victoria are traditionally the main suppliers of southern hemisphere grapes although as a result of a dispute over outturn, Victorian exports to Singapore were suspended in 1970 and South Africa and Argentina increased their shipments. However a new contender - Thailand - has entered the field and could play a significant role in this market. The climate in the grape growing area of Thailand is such that vines have no true dormancy and by pruning soon after harvest, new growth is forced out which flowers and sets fruit, much as grapes do in the north west of W.A. This means that Thailand can supply grapes virtually throughout the year although the peak harvest period is May to July, and while the quality is not particularly good the regularity and freshness of supply will help promote their sale. The grapes are red (claimed to be Cardinal) and green (said to be White Malaga). They are packed in 30 lb baskets and air freighted each day to Singapore. They are carried by Thai Airlines over the 900 mile trip, at an apparently subsidised rate, which works out at about 9 cents (Aust.) per lb. The market is therefore likely to be supplied with cheap grapes the year round and this could have a detrimental effect on the prices obtained for our grapes. The Thai grapes are also being sent to Hong Kong. The Australian Trade Representative in Bangkok advises that Thai grape growers are also interested in growing grapes for wine and considerable areas are being planted (currently 7,500 acres).

This new competition should be watched very closely as it could well prove a determining factor in the quantity of grapes Singapore importers are able to take from Australia and also the price they will pay.

Citrus Fruits. Oranges and mandarins make up the bulk of citrus shipments to Singapore. In 1972 Chinese mandarins and Australian oranges each made up about 30% of imports. Israel also shipped about 24%, leaving Formosa, U.S.A. and South Africa with somewhat less. It is thought that in 1972 South Africa probably shipped about 300,000 bushels. Israel sends all fruit on consignment and has its own office in Singapore to organize distribution.

Export from Singapore

Approximately 40% of all fruit imported into Singapore is transhipped to further destinations - mainly Malaysia. Limited quantities go to Indonesia. Sales are made to wholesalers in these countries according to the market conditions of operating. Both countries have high duties which make this trade unattractive in that the Singapore importer has to pay the duty at time of entry and give the buyer a month's grace to settle the

account. In both Singapore and Malaysia sales at wholesale level are effected by private treaty in a variety of wholesale markets. At retail level much of the selling takes place from street stalls and hawkers' barrows. Only a small proportion is sold pre-packaged through supermarkets. At the time of my visit apples were selling at three or four per Malaysian Dollar. Oranges were cheaper at five per Malaysian Dollar. The retailers, as far as possible, pick up fresh supplies each day as fruit deteriorates quickly in this Singapore-Malaysian climate.

Although the preference in Asian markets is for red apples, the rapid deterioration which occurs in the tropical climate and the poor handling conditions actually favour the Granny Smith and from an importer's point of view is a much safer apple to handle. For this reason it must continue to hold a place in the marketing programme for many years to come.

HONG KONG:

Hong Kong as a free port can receive fruit from any destination and this makes the trade very competitive. There is no significant local production of any fruit and with a population of 4 million people, large importations of a wide variety of fruits are needed to meet the local demand. Imports of fresh fruits are currently running in the region of 300,000 tons (\$A 50 million) per annum of which half comes from China, about 20% from the U.S.A. and 16% from Taiwan. Australia's share is less than 2%. Other suppliers include South Africa, Israel and the Philippines. Oranges are in heaviest demand followed closely by apples and pears. These three kinds of fruit make up half the fresh fruit requirement of the colony. Other fruits include bananas, mandarins, grapes, mangoes, stone fruits, lemons and grapefruit.

The positions of China and other neighbouring Asian countries as suppliers to the Hong Kong market are unchallengeable due to low production and freight costs. Also, as a high proportion of the population is Chinese (many quite recent arrivals), they favour the types and varieties of fruits from this source.

The United States over the past 30 years has painstakingly built up a solid market in Hong Kong and their products, (citrus, apples, grapes and stone fruits), are held in high esteem and bring premium prices. Australia's stake is quite small and carries little weight in the market. Her main contribution is apples but these comprise only 6-7% of apple imports as against China (70%) and U.S.A. (10%). Tasmania's share of the Australian supply is a quarter of a million bushels but shipping is difficult and deliveries in 1972 are expected to be

below requirements. A further 50,000 bushels is supplied, half by W.A. and half by other eastern States.

Uncompetitive prices, shipping difficulties and more variable produce have prevented Australia from gaining greater penetration of the market. As far as W.A. is concerned another factor is its inability to supply red apples which the Chinese prefer. Importers complain of having to discount Granny Smiths, as the popular taste is for Red Delicious type. The Chinese are apparently very fastidious about food and traditions and customs play a large part in their likes and dislikes. For instance, apples must not be flat and preferably have a prominent crown and red in colour. Citrus must be well coloured with thin, finely textured skin. Grapes and plums must be large. A favoured plum is the Kelsey. Pears also need to be very large to attract the best prices and Packham counts as low as 60 are in demand.

Provided prices can be kept at reasonable levels, there will remain a place for Australian fruit on the Hong Kong market. However, it is a very selective market due to the broad spectrum of supply available and special care is necessary in choosing fruit for this market.

JAPAN:

In spite of a large local fruit production Japan is also a large importer of fresh fruit. The value of imports is in the region of \$A17⁵ million per annum, but this includes a large proportion of tropical fruits.

In Tokyo the air of affluence which pervades the city is reflected in the very high price structure. Both goods and services are expensive and this applies equally to fruit. It appears to be one of the highest priced retail fruit markets in the world. Japan imports considerable quantities of citrus, bananas and other tropical fruits but strict quarantine requirements prevent the import of apples. The United States is well established as an exporter to Japan and some Pacific countries such as the Philippines and South America also regularly ship to Japan. Recently South Africa and Israel have gained entry for their citrus fruits.

Imports:

Because of Japan's freedom from codling moth and various species of fruit flies, it has very strict plant quarantine requirements governing fruit imports. Imports from Australia are banned on account of codling moth in the case of apples and pears, Mediterranean and Queensland fruit fly for citrus, grapes and stone fruit and melon fly in the case of melons.

Japan has a very considerable production of apples and pears, also a large production of mandarins but needs to import lemons and grapefruit in quantity, mainly from the United States, as the climate is generally unsuitable for these crops. In addition, stone fruits, some grapes and melons are grown.

Imports of lemons from the United States are increasing and in 1971 amounted to \$A26.5 million. Last year New Zealand entered this field in a small way and South Africa and Israel shipped oranges and grapefruit for the first time. Orange imports have been strictly governed by quota but this is now expected to be liberalized. So far the United States have been able to insist on forward sales of lemons at a price of \$9 to \$10 a box. South Africa and Israel on the other hand are sending citrus fruit on consignment and this could affect the Americans' hold on the trade. The largest fruit import is bananas, which in 1970 exceeded \$A130 million.

Fruit requirements will no doubt increase with the rising standard of living. It will be difficult to expand local fruit production due to the shortage of land and the inroads of industrial expansion, so that Japan will probably look to imports as a means of satisfying the demand. Japan's balance of payments are also heavily in her favour and she will no doubt be anxious to offset international monetary pressures by increasing imports.

Fruit Prices:

Tokyo is a high priced market for fruit. At the time of my visit high class shop prices were astronomical with a presentation basket of fruit costing as much as \$40. Early musk melons were being offered at \$9 each, water melons \$6 each and early hot house, large grapes in special boxes up to \$14 a bunch. Fruit is commonly given as a gift in Japan and hence the special packs and this perhaps explains some of the high prices paid. Departmental stores were a little more reasonable and small street shops were the cheapest but even here fruit was still quite dear.

By comparison wholesale prices quoted in the press were as follows:

Apples (local red) 80 count	-	4,700	¥ per 16 kilo
92 "	-	3,300	¥ per 16 kilo
100 "	-	2,800	¥ per 16 kilo
112 "	-	2,300	¥ per 16 kilo
120 "	-	1,600	¥ per 16 kilo

Apples green unspecified count	-	2,700	¥ per 16 kilo
Prince melon	-	80-240	¥ per kilo
Watermelon	-	12- 94	¥ per kilo
Grapes	-	220-800	¥ per kilo
Peaches	-	60-400	¥ per kilo
Plums	-	120-290	¥ per kilo

The pertinent observation is the price differential of apples according to count where the difference between 120 and 92 count can mean doubling the price.

Need for Imports into Japan:

One importing company was quick to point out that Japan was not in urgent need to import fruit as it has local supplies the year round although certain kinds of fruit which cannot be grown in Japan such as bananas, pineapples, lemons, etc. must be imported. The local production of apples exceeded 50 million bushels and not many years ago Japan was exporting apples. During my visit which was very late in the season, large apples could be bought freely in the shops. They were mainly the red Kokko variety which makes up half the present production. It is a red striped apple somewhat resembling a Delicious in appearance. However, although extra fancy in appearance and in excellent condition, the fruit was absolutely devoid of flavour. Green apples on sale were also excellent in every way except flavour. They were sour and astringent and only suitable for cooking. The western Granny Smith would compete very well quality wise at this time of the year, but there would no doubt be strong pressure from the industry tempering any government action. This is evidenced by the strong opposition to increased imports of oranges and also grapefruit - a fruit which is not grown to any extent in Japan. In June, 1971, 2,300 fruit growers including apple growers attended a meeting in Tokyo to protest to the government against liberalizing imports. This type of pressure is no doubt influencing the government's hard line in apple imports. I was told that there are adequate cold storage facilities to handle the local apple crop, including C.A. storage and obviously the operators understand storage even if the varieties may not retain good flavour for the full season.

The Japanese favour red apples and the popular choice for new plantings is Starking type Delicious.

It was suggested that, subject to quarantine requirements, there could be an opening for medium to small Australian apples, including Granny Smiths, as the large apple market is well

supplied. However, in view of the price differential for size, this does not seem a very sound proposition unless it could provide an outlet for some smaller sizes if the U.K. market is curtailed.

Sources of Supply

Without specifically naming them, it was stated that many countries would be interested in shipping apples to Japan if quarantine requirements permitted. Australia has the advantage over some of them in being a southern hemisphere supplier and relatively near to the market. South Africa could become interested, if, as is likely, she will soon be looking for new outlets for apples, and if an acceptable treatment for codling moth is found. Western Australia has a technical advantage in being free from codling. If Australia is to keep ahead of other possible contenders, it was suggested that prompt action was necessary to present a case, supported by experimental evidence if possible, to pave the way for round table discussions between the two countries.

The Whole Australian Concept

All personal approaches to date have failed to break down the concept of applying Japanese plant quarantine requirements to a whole country rather than to any part of it. The various arguments of freedom from certain pests in some States, Western Australia's isolation and strict quarantine measures and disinfection programmes in progress are well known and it is said that the only way progress will be made is by direct discussions at high level to determine what areas of negotiation exist. The initiative of South Africa and also Israel in successfully pressing their cases for agreement on citrus imports is cited.

Quality Requirements

The Japanese will not accept second best; all produce has to be near perfect and a good example is the citrus fruit from California and Arizona. It is not a question of a lower price for sub-standard produce, the Japanese just will not accept anything which does not measure up to their high standard. Strict adherence to specifications is taken for granted.

In talking to a citrus importer (Fujii Hajime Co. Ltd.) I gathered they were more interested in the importation of oranges and grapefruit than lemons - possibly because of the expected easement of orange quotas. South African navels had been a little disappointing because they arrived in a green condition and did not develop a satisfactory orange colour. Good skin

colour is important in Japan. There was very favourable comment concerning oranges seen by visiting Japanese in South Australia.

Looking at the Japanese scene as a whole, it seemed very apparent that this is a future fruit market well worth exploring. The United States, which already has a very lucrative trade in citrus and tropical fruits and South Africa and Israel who are anxious to obtain a share are alive to the future potential and have been active in gaining entry. The general view in Japan seems to be that Australia, although well situated geographically, is doing the least to gain a place in the market and requires a more forceful approach, both scientifically and administratively, to find solutions to the current problems of entry.

FUTURE PROSPECTS IN SOUTH-EAST ASIA

There are no immediate prospects for substantial increases in fruit exports to the South-east Asian region although additional quantities of Red Delicious could be placed. Markets in this area are becoming more competitive as various countries seek to increase their trade in fresh fruit. Variety preferences are changing, particularly towards red varieties of apples, grapes and stone fruits and importers are becoming more selective. It is important that high quality standards and specifications be strictly adhered to if the position enjoyed by Australia is to be maintained and we must supply preferred types of fruit. If this is not done the trade may pass to other suppliers.

As far as Japan is concerned there would appear to be a good potential, if not at present, at least in the foreseeable future, provided a concerted effort is made to satisfy quarantine requirements.

DEVELOPMENT OF FUTURE OVERSEAS EXPORT TO EUROPE

W.F. Walker^{*}

Over the last two decades it has been extremely difficult to forecast with any degree of reliability market supply and demand for fresh fruit and vegetables in European countries.

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The pome fruit market prospects are no exception and they are influenced by many diverse factors.

Consumer demand can be influenced by such unpredictable factors as localized and general European weather conditions as well as the availability of other imported horticultural produce. The regularity of supplies of home-grown produce is another variable which makes prediction difficult.

In some European countries, due to their geographic location, local production of certain kinds of fruits and vegetables is naturally restricted. Horticulture, particularly production of vegetables, is protected economically to a considerable extent in Europe. The extent of likely restriction in supplies from third countries by the application of various European Economic Community regulations has been very difficult to predict. Even now it is not easy to anticipate the interpretation of various restrictive regulations concerning grade standards and such limitations as missing stalks in apples.

In spite of developments in variety selection and rotation and advances in fruit storage and preservation, it is still very difficult for any country to become entirely self-sufficient in the production of deciduous fruits. The day to day supply of many fruits for the masses of consumers cannot be adequately provided by holding out of season requirements in cold storage. The over-storage of fruit, of apples in particular, has been common in many markets in an endeavour to bridge gaps in supply before the new season's crop is harvested. There are still countries in Europe which rely almost entirely on locally grown and other northern hemisphere fruit to meet their needs. This inevitably results in the marketing at the end of the season of much fruit which is of low grade and in poor condition and this causes buyer resistance. It is apparent that industry in both the northern and southern hemispheres is still not fully utilizing the results of fruit storage research. Often in an endeavour to meet the market needs for apples between seasons, there is a real tendency to harvest the next season's crop too soon. As a result, and, influenced by firm market returns, immature and somewhat inedible fruit is frequently supplied to the consumer.

The position becomes magnified in seasons of local crop limitations and failures which, however, can be forecast. Furthermore, it is reasonable to assume this year that the European apple supply position could 'dry up' much earlier than usual in heavy crop years.

How much longer will the consumer continue to pay high prices for inferior, immature or over-stored fruit? It has always

been incredible to witness the extent to which the British, and the European consumer, will buy new season's and locally grown fruit of rather doubtful quality and edibility.

In some years during the months of August and September and sometimes early October, large quantities of low grade English apples have been marketed at prices in excess of those paid for Australian fruit of superior quality. Although it is realized that the English apple crop was both later and lighter this season, the housewife had to pay up to an equivalent of 70 cents per lb for some fruit compared with 30 to 40 cents for Australian fruit in September. However, during the summer period high quality imported fruit retailed at prices approximating 20 to 25 cents per lb.

Tasmanian apples have to compete not only with increasing supplies from South Africa and New Zealand, but also with an extended South African marketing system. The range of other kinds of fruits on the market is also increasing, stone and berry fruits from other European countries have extended and expanded the supplies of these fruits on the British and European markets. The variety of supply is being widened with grapes from Greece, mixed fruit from Israel and Lebanon and air transported tropical fruit from African countries. There is a much wider selection available to the consumer, but his spending power does not appear to have increased, in fact, it could have decreased as a result of generally rising costs.

In spite of the difficulties in the United Kingdom and other European markets, there is no cause at present to cut off the Australian supply. It is obvious that rising freight rates will increase the landed cost of Tasmanian fruit on European markets and a heavier tariff at the same time would be crippling. However, any thought of such a tariff on Australian fruit imports as soon as the United Kingdom joins the E.E.C. must be surely speculative.

The phasing out period from E.E.C. markets may be somewhat longer than some authorities would anticipate at present. The Argentine apple and pear industry producing 20-25 million bushels expects a considerable increase in trade in the United Kingdom in the future. A careful reassessment of the entire marketing and fruit supply position in all European countries is needed.

Another aspect becoming more important in production and marketing overseas is the movement of fruit from the tree to the consumer. The present cost of putting Australian apples on European markets at the retail point ranges from 10 to 14 times the cost of producing the fruit, we must review the increasing, costly, sophistication of our marketing chain. Fruit grown in

close proximity to the point of consumption has shorter distances to travel and does not need expensive protective packaging. A review of our harvesting, sorting, grading and packaging procedures, to meet modern methods of retailing, could be worthwhile and possibly rewarding.

In looking at markets closer to Australia, and even within Australia itself, one could ask whether the consumer is really getting the kind and type of fruit he wants, or is this decided by the importer and retailer? The high cost of sophisticated packaging of fruit for export to countries with a lower standard of living naturally restricts consumption to the more affluent minority. Any means whereby bulk fruit shipments to such countries could be sorted and handled by local labour might widen the range of consumers able to purchase the fruit.

Although it is inevitable that Australian fruit shipments to Europe could be phased down to lesser quantities, there does not seem to be any sound reason for the supply to be cut off as abruptly as some authorities are prepared to predict.

The Australian export pome fruit industry has been alerted on a number of occasions in the past to the problem of increasing world production and keener competition on world markets but the challenge of changing conditions has not been accepted by a fully united approach. Efforts over the last 2 years to expedite the loading and unloading of overseas ships, by unitisation and bulk shipments are appreciated, but still greater efforts are needed to supply the consumer with what he wants at reduced cost.

SYMPOSIUM DISCUSSION

In the United Kingdom the future export potential for dried fruit is less promising than that for fresh fruit. Our quality advantage over Turkey and Greece has been reduced due to improvement in the quality of their produce, and we are at a freight disadvantage in comparison with these countries. A shipment of Australian lemons in 1971 achieved very ready acceptance and was considered as good in quality as the Californian lemons. The English housewife prefers bright yellow lemons.

Shipment in bulk bins allows about 30% more fruit to be shipped in a given space compared with in cartons. This could become important with increasing freight rates and reduced availability of shipping space.

One delegate considered that Australia should look for new varieties to replace the Granny Smith apple on the market in Europe because of extensive plantings of the Granny Smith in France.

In Asia the Hong Kong market, where there is a good market for ships' stores as well as for local consumption, could be exploited much more by Australia.

The domination of the marketing boards by producers was considered to be unsatisfactory, important decisions should be made by trained people, not by laymen.

It is clear that our quality control must be improved to hold existing markets and to find new ones and the costs of handling and packaging must be reduced for our horticultural exports to remain economically viable. Promotion has a place but it must get right through to the consumer.

CONFERENCE SUMMARYE.G. Hall^{*}

In the beginning Ray Brough, the chairman of the Conference, stressed the current and future importance of packaging and handling and the economics of marketing. I think that the papers you listened to in the Conference and the discussion arising from them, have really brought this out, and this has been one of the really big changes in the Conference this year.

One might put this in very down-to-earth terms: that we have been, more than we have in the past, concerned with the hard economics of the fruit and vegetable industries. The work has been more directed towards cutting costs and saving the industry money, and this is what the industry needs. Overall it is in a pretty desperate economic situation.

I would like to refer to most of the papers and comment on them. Brian Beattie opened very courageously and undoubtedly he was the most 'colourful' character present. Brian wondered whether there was a classic supply-price situation in the marketing of apples out of cool storage. Quite frankly I'm not sure whether there is or isn't; I think we will be in a better position to know when we see the result of Brian's work in full, which will appear later as a thesis.

Dr Greenhalgh gave us a start on what is quite important, looking at quality-price relationships on the market and the question of consumer satisfaction. This is something to which we have not given much thought in the past, and it is a question to which we must give a lot more thought in the future. In other words, we have to think a lot more about the consumer and his needs. I would like to commend Merv. Littman for his enthusiasm in coming down to this Conference privately, paying his own way.

He gave us an interesting attempt to improve our basic thinking in looking for optimum storage conditions, and it is always refreshing and salutary to have somebody come along and question the basis of our thinking on these matters.

We were fortunate in having Dr Wishart to open the Conference and I think we were also well guided and well advised by him when he pointed out that we must not only think of the grower but also of the consumer and perhaps, more importantly, that we must aim as much of our work as possible to reducing costs,

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not only in the interests of the grower but also in the interests of the consumer.

Since the last Conference there have been tremendous, and I think tremendous is the only word for it, developments in packaging; Ian Peggie has been a spearhead in this and he deserves great credit for it. He and John O'Loughlin have done a great deal for the apple and pear industry in bringing about very big changes in the packaging and handling of apples and pears for export and this is also having its effect on the local market. It is very interesting and very important and a lesson to all of us that this kind of work has been readily and widely accepted by the industry because it has been quite obvious that it is going to save it real money.

All of us are public servants, and we are all being paid out of public funds, therefore we do have a responsibility, when asked, and perhaps even when not asked, to stand up and be accounted. That is, we have to satisfy not only ourselves but others that the work we are doing is of real economic value to the industry and to the economy of the country. The kind of work which Ian Peggie and John O'Loughlin and others have been doing does stand up to this test.

The question of returnable packages for marketing of fruit and vegetables internally is now under consideration. You have heard something about this in the Conference. Potentially I think this is the greatest cost saving the industry is likely to achieve for a long time to come. I understand that one of these approximately bushel-sized returnable plastic packages will cost something like \$2.50 to make but that the one use cost would only be a matter of 10 or 15, or at the most, 20 cents. When one compares this with 50 or 60 cents or more for the present cost of packaging then here is probably a life saving cost reduction for the industry, and therefore I believe it is one that we should support to the utmost, technically and in any other way we can.

In the field of handling I consider it is very good that we are working with a wider range of people, for example we had with us representatives from the National Materials Handling Bureau and the Bureau of Agricultural Economics. I think we should work more closely with these people and not only should we be working with the Materials Handling Bureau on the mechanics of materials handling, but we should be also working more closely with people in the Bureau of Agricultural Economics and economists in the State Departments of Agriculture on the economics, the costs and returns, arising from new practices that we might like to suggest as a result of research. It is of considerable satisfaction to me that the New South Wales Department

of Agriculture has on its staff in the Division of Horticulture, Brian Beattie who is working in the field of the economics of horticultural practices, and I would hope that other States would follow this lead, because, in the past, a great deal of what we have done has been done without relation to the basic problem of costs and returns in the industry.

A rather pleasing feature of this Conference, reflecting its much broader nature in comparison with past conferences, is that we had two representatives of two universities here taking an active part in our deliberations, and presenting work to us in the form of short papers resulting from work of students in these universities. Nothing but good could come out of this broadening of our relationships, and I think it is a very good thing for ourselves, for the fruit and vegetable industries and for the universities that they have been recently taking an active interest in research in the technical and scientific problems of the marketing of fruit and vegetables. It is often said that fruit and vegetables are not a very important industry in Australia, but if one looks at the total value of the production it is very significant in the economy of the country.

Packaging has loomed very largely, and very properly, in the deliberations of this Conference; I just cannot leave this subject without referring to the paper by Dick Schoorl, regrettably absent, who is at present the only full time packaging research officer in Australia. It was a very good move by Queensland to appoint such a person. The value of Dick Schoorl's approach to packaging and handling problems is that it is almost from a strictly physical and engineering aspect and this is going to be refreshing and very useful to the rest of us who are primarily biologists.

The Symposium on Export Development I personally thought was unduly cautious. Certainly no false hopes were raised and perhaps this was foremost in the minds of the three speakers. But it was made quite clear to us in what they said, and in the ensuing discussion, that we can and we should do a lot better in exporting the traditional commodities which we have been sending abroad for so long. And here I must again say, as I have said in other places, that it seems to me fundamentally wrong, and this seems to be unfortunately a peculiarly Australian characteristic, that we grow or produce, or manufacture something, put it in a package, stamp 'Made in Australia' on it, send it overseas, and then confidently expect that somebody, somewhere, will pay our price for it. This is basically wrong thinking by Australian industry, and unless there is a change in thinking, which we must support, I do not believe it has

very much future. The production, handling and packaging of our produce must be market oriented and not production oriented. A product must be produced for a market: if you just go looking for a market for something that you have already produced you will probably not find it.

On the engineering side we had two very useful contributions from Dick Atkins and Peter Holligan, who jointly showed us how C.A. stores should be built and how they should be run. Dick, in particular, showed us the wide prevalence of poor practices. I think one of the lessons here, and I am sure the Chairman of today's meeting would take due notice of this, is that it shows the very urgent need for post-harvest extension specialists. Cool storage is one aspect of handling fruit and vegetables after harvest which has been crying out for really good technical help and advice for a long time, help and advice right down to the grass roots level. It is just incredible that people can go on building and operating cool stores in the crude way that has been so clearly illustrated.

Controlled atmosphere storage has now been with us for some years and a large proportion of the apples which are marketed, particularly late in the year, go through C.A. storage. Therefore it is very useful that John Blake gave us a very detailed review of C.A. storage and I must commend him for having this so well documented. We do have the responsibility to see that C.A. storage is much better managed than is so often now seen around the country, not only in small stores but also in some of the very large stores where they should know a lot better.

One of the very big developments, and one which is perhaps going to have more potential than anything else since the last Conference, has been the development of the ethylene scrubber, which has primarily been the work of Kevin Scott. I am sure that this is going to be tremendously important in the five-year period until the next Conference, and I would expect that by then you will find that this technique of not only managing the temperature and humidity of the environment around the stored and transported fruit and vegetables but also the composition of the atmosphere will be widely applied. This will be not only in terms of CO_2 and O_2 but also of the volatiles, these compounds present in minute quantities which we are coming to know to be so important.

Apple breakdown received a good deal of attention; there has been a lot of research done since the last meeting. We are approaching an understanding of the nature of this disorder, but there is still much more work to be done before we have a practical method of control. It is still an important problem which is well worthy of continued attention.

Unfortunately bitter pit, which has been the mainstay and the hope, and at the same time the bugbear of Don Martin for almost a lifetime, remains a problem. If only growers would not export light crop fruit! If only research workers would take full account of fruit size by measuring the mean crop size of everything they work with! Don, you are going to retire between this Conference and the next. I do hope for your sake and for the sake of everybody else that they will at last heed your advice, which has been so conscientiously put forward year after year.

The paper from Stan Hardisty indicated the importance of tree management. I feel that this is something to which we have not paid sufficient attention and something of which a great deal more use can be made in the future. Trees are capable of much more management directed at producing the best kinds of fruit for the various requirements than we have recognized and accepted in the past.

In my mind and in the minds of perhaps a number of you there must have been quite a large question mark raised during the last few days over C.A. storage. Is it being overdone? Is the consumer being hoodwinked? Have we been conniving in that hoodwinking of the consumer? I have a rather guilty feeling that in some measure we have. Perhaps this is only another way of saying that in the past we have not been giving enough thought to the consumer. Without the consumer there is no market, and without a market the producer has nothing. I do believe that not enough attention has been paid to the eating quality of the fruit out of C.A. One of the factors about which I feel quite strongly is the maturity of the fruit going into C.A.; there are other factors too: temperature, the composition of the atmosphere, and I would commend to you younger people who are going to carry on the investigation after we oldies have quite properly disappeared from the scene, that you should pay much more attention to the eating quality of fruit that arrives on overseas markets, to the eating quality of fruit and vegetables which have been given what we might think to be a superior treatment.

Before I leave this question of eating quality I must pay somewhat belated personal tribute to a former colleague, George Tindale, who was more right than many of us at the time would admit, in plugging for the importance of eating quality and its serious consideration in any storage work. George was blessed with a very acute, perceptive, palate and the lesson here is that we should pay much more attention to consumer satisfaction in everything we do.

However, we mostly do have our feet on the ground and this has been well exemplified by the short paper from John Watkins from Queensland in which he showed us how simply the concentration of diphenylamine in the dip tank could be measured. This will be of very great practical use.

There was quite a considerable discussion of that perennial and very vexed question, apple maturity. We heard from some of the young bloods at Scoresby of new approaches to this old problem of trying to determine reasonably accurately fruit maturity. The report of the work on anthocyanins as a possible means of predicting maturity was a good one. This is an appropriate place to say that I personally was very impressed with the attitude to their work of the young people who have come to this Conference for the first time and the performances they have given us during the last few days. Perhaps this might possibly be called the conference of the young Victorians, there is potentially a very good team at Scoresby.

Four years ago at the last Conference chemical control, not only of maturation but also of post-harvest behaviour was something which was just around the corner. What you have heard at this Conference has shown that we now have this right with us, and the papers by Barry McGlasson, Nick Veinbrants and Terry Lee have demonstrated quite exciting possibilities for chemical control of the crops with which we are directly concerned. In fact, I think we now have the possibility of improving on nature.

In the last 4 years there has been another development with again very exciting possibilities, which Barry McGlasson told you about. It is the work of Drs Raison and Lyons and their phase change theory in relation to hibernation of animals and to cold injury, and resistance to cold, in plants, which we are now given to understand are basically of the same nature. This work opens up possibilities for promising new lines of study of this important problem of cold and chilling injury which, for as long as I have been concerned with fruit storage work, has been one that has been put in the 'too hard' basket. Perhaps it can now be taken out of that basket and real progress made.

George Strachan, unfortunately our only representative, but a very worthy one, from New Zealand, again entertained and informed us with more stories about these peculiar and pet fruits he has got over there, the Kiwi berry and this pseudo tomato, the Tamarillo. Seriously, these are interesting in their own right.

We go to other crops. Grapes remain a problem. Until some satisfactory method of controlling wastage during storage is developed, we are not going to see much progress in either export of grapes or in their storage for the local market. Clearly, there is a need for both. I hope that work will continue

in this area and that it will lead to some effective way acceptable to industry of ensuring that grapes do export and keep well.

Bananas, those physiologically very interesting but often 'problem' fruits, also had their moments during the Conference. Bruce Peacock emphasized the importance of good fruit-rot control in relation to green-life. I think that this is very important to the industry and I hope that his message gets right back to them. Tim Trochoulis showed us that the question of banana ripening is not as simple as a lot of people think, perhaps the banana is very susceptible to changes in environment at the climacteric period. This work is of importance to the consumer because consumers should get good eating bananas wherever they may be in this continent of ours, where there is an enormous range of climatic conditions, from the arctic frigidity of the southern part of Tasmania to the hot dry interior and the tropics of the north. It is part of our responsibility to see that consumers, wherever they are, can get bananas and other tropical fruits, and also temperate fruits, in good condition and of good eating quality. It is a shame, and a reproach to us horticulturalists, that a lot of people in this country are denied the enjoyment of tropical fruits because the technology of how to transport them and make them withstand these diverse conditions is not known.

Finally, there are some general comments about the Conference which I feel must be made. A feature of this Conference in relation to previous ones, and there have been a number, starting back in 1946, with a gap to 1956 and then at four-year intervals, is its much wider scope, in the people who have been attending, in the disciplines concerned, and in the type of papers presented. This widened scope of the Conference is very good, and I would hope that future conferences and the work that you people collectively will do, will also be similarly wide in scope.

We do need more help from economists and engineers to make the work of most of us, who are primarily biologists in the broader sense, more effective, for both the production industry and the consumer.

The importance of ethylene and of its removal has been stressed. Perhaps a controlled environment concept is developing from what we have known, perhaps more restrictively, as a controlled atmosphere concept.

As I said earlier, we had a number of new faces at the Conference; these new faces have looked good and they have performed well. I do believe that the whole standard of production and presentation of papers and of discussion of them at the Conference has been better than at previous conferences. This is

how it should be, unless we improve in each four-year and five-year period we are in fact going backwards.

One of the main advantages and benefits of a conference like this is not so much the formal part, the papers presented, but the informal part, the personal contacts that are made and the opportunities for informal discussion. It has been said by our hosts here, with some astonishment I gather, that this has been the hardest working conference that they have had. It is quite right that we should have been hardworking, as that is what we have been here for.

The proceedings of the Conference do form a very useful record, and I believe that the published proceedings are one of the important benefits of such a meeting.

In the future it appears that this Conference will, if it is lucky, and I hope it is, be held at five-yearly instead of four-yearly intervals. I do believe quite sincerely that it stands well in comparison with other conferences which are recognized and given the seal of approval by the Standing Committee on Agriculture. As a complement to the production side, i.e. to the fruit and vegetable research conferences, I would see our conference becoming more important. I feel that the Commonwealth and States Horticultural Committee, and the Standing Committee on Agriculture, will be recognizing the increasing importance of the meeting of a group such as ourselves concerned with the increasingly important problems of how to sell a crop which, comparatively, is more and more easy to produce.

If these conferences are to be on a five-year basis I commend to the policy makers that there should be more opportunity for specialist group discussion meetings within those five-year periods. Although I am now at long last becoming averse to committees I feel that perhaps there might be more technical sub-committees of the same type as the Pome Fruit Packaging and Handling Sub-Committee and the Murray Citrus Sub-Committee which have proved their worth. Perhaps there could be specialist sub-committees which could meet, if not annually, then at least every 2 years to formalize opportunities for the research workers to get together in conference and in informal discussion. Nothing but good can come out of that. Despite the wonderful technological developments in communication, difficulties of communication between people still remain one of the great problems of the present age.

In formally taking my leave of this Conference and of you people I would like to say that this is increasingly a young man's world, and therefore I feel it is time I went. I am sure that both Don Martin and Dick Atkins, who will be retiring

between now and the next Conference, would agree with me that we are leaving fruit storage research in Australia in very good hands and that there is great potential for very good research in the interests of the industry in the young people we have seen at this Conference.

SIXTH AUSTRALIAN FRUIT AND VEGETABLE STORAGE RESEARCH CONFERENCE

RESOLUTIONS AND RECOMMENDATION

The Conference passed the following resolutions, for consideration by the Committee for Co-ordination of Fruit and Vegetable Storage Research and transmission to Commonwealth and States Horticultural Committee:-

RESOLUTIONS

- (1) The Conference believes there is a continuing need for export fruit and vegetable trials and that the success of such trials depends on adequate technical assessment. It therefore recommends that an approach be made through the appropriate channels for Commonwealth and industry funds to enable research personnel to travel overseas to examine and report fully on the outturn of approved trials.
- (2) The Conference again recommends that State Departments of Agriculture appoint post-harvest specialists to work in the field of fruit and vegetable handling, storage and marketing, as there is now an urgent need.
- (3) The Conference recommends that C.S.H.C. consider the desirability and means of establishing, in Australia, the equivalent of the Marketing Facilities Branch of the Marketing Research Division of the U.S. Department of Agriculture.

In addition, the Conference recommended to the Committee for Co-ordination of Fruit and Vegetable Storage Research as follows:

RECOMMENDATION

That the Organizing Committee consider for the next Conference a section on harvesting and packaging machinery.

Reason

The aim of all post-harvest research is to present an acceptable product to the consumer at a future time and place. If the quality of the fruit or vegetable is jeopardized in any way after maturity this must of necessity increase the potential for spoilage. The use of machinery for harvesting, handling and packaging is increasing and most machines demand expert design and handling so as to reduce harvest and packing damage. Specialists are now available to research these facets. A section devoted to a review of machine development, with contributions on adjustment, effects, and sanitation is therefore warranted at future conferences.

G. Fisher
Conference Secretary

LIST OF DELEGATES

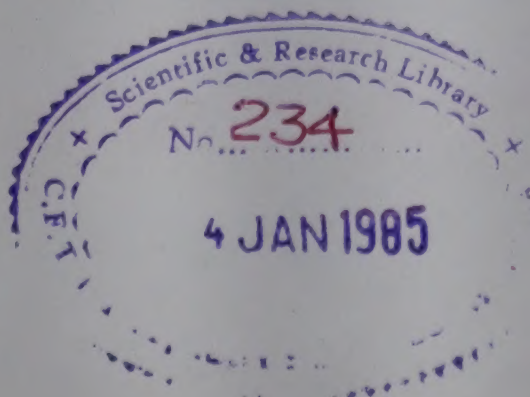
Atkins, R.	CSIRO Division of Food Research.
Beattie, B.B.	Department of Agriculture, New South Wales.
Blake, J.R.	Queensland Department of Primary Industries.
Brough, C.R.	Department of Agriculture, Victoria.
Cerny, J.	CSIRO Division of Horticultural Research.
Chalmers, D.J.	Department of Agriculture, Victoria.
Dundas, K.C.	Bureau of Agricultural Economics, Canberra.
El-Zeftawi, B.M.	Department of Agriculture, Victoria.
Faragher, J.	Department of Agriculture, Victoria.
Fisher, G.	CSIRO Division of Food Research.
Flynn, C.	Commonwealth Department of Primary Industry.
Graham, D.	CSIRO Division of Food Research.
Greenhalgh, W.J.	University of Sydney.
Hall, E.G.	CSIRO Division of Food Research.
Hardisty, S.E.	Department of Agriculture, Western Australia.
Holligan, P.J.	Department of Agriculture, New South Wales.
Johnson, J.F.	Department of Agriculture, New South Wales.
Kinsella, M.	Department of Agriculture, Victoria.
Lee, T.H.	University of New South Wales.
Leggett, E.K.	Department of Agriculture, New South Wales.
Leggo, D.	Department of Agriculture, New South Wales.
Lewis, T.L.	CSIRO Division of Horticultural Research.
Little, C.R.	Department of Agriculture, Victoria.
Littmann, M.D.	Queensland Department of Primary Industries.
Long, J.K.	Department of Agriculture, New South Wales.
Martin, D.	CSIRO Division of Horticultural Research.
McGlasson, W.B.	CSIRO Division of Food Research.
Melville, F.	Department of Agriculture, Western Australia.
Minnis, D.	Department of Agriculture, Victoria.
Newman, B.J.	Department of Agriculture, Victoria.

O'Loughlin, J.B. Department of Agriculture, Tasmania.
 Peacock, B.C. Queensland Department of Primary Industries.
 Peggie, I.D. Department of Agriculture, Victoria.
 Riley, T.J. CSIRO Division of Food Research.
 Rippon, L.E. Department of Agriculture, New South Wales.
 Scott, K.J. Department of Agriculture, New South Wales.
 Seberry, J.A. Department of Agriculture, New South Wales.
 Spicer, R.W. Department of Agriculture, Victoria.
 Strachan, G. Plant Diseases Division, D.S.I.R., New Zealand.
 Trochoulis, T. Department of Agriculture, New South Wales.
 Tugwell, B.L. Department of Agriculture, South Australia.
 Veinbrants, N. Department of Agriculture, Victoria.
 Walker, W.F. Department of Agriculture, Tasmania.
 Webber, R.T.J. Department of Agriculture, South Australia.
 Wild, B.L. Department of Agriculture, New South Wales.
 Wright, A.G. National Materials Handling Bureau.

Visitors

R.S. Harper)
 R.A. Mullett)
 H.J. Taylor)
 R.M. Pedretty)
 G.E. Martin) Department of Agriculture, Victoria.
 P.T. Jenkins)
 J.H. Whan)
 T.J. Piggott)
 G.W. Gayford)
 J.E. Kenez)

Associate Professor G.E. Stembridge,
 Clemson University, South Carolina, U.S.A.

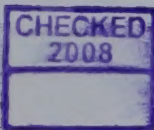


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